Electricity I

Dr. Kimball. C. L. Poor

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# Electricity

Dr. Kimball.

Dec. 1/88.

Chas Hanchett.

We shall start with Coulomb's law

$$F = \frac{qq'}{r^2}$$

and from some relations from it.

There are two kinds of quantities; vectors, velocity, Electro-motive force,

scalar - energy, work ideas of directions, as density, mass. Energy.

A thin circular disc of attracting matter, & finite its attraction upon unit mass placed at distance h above its centre.

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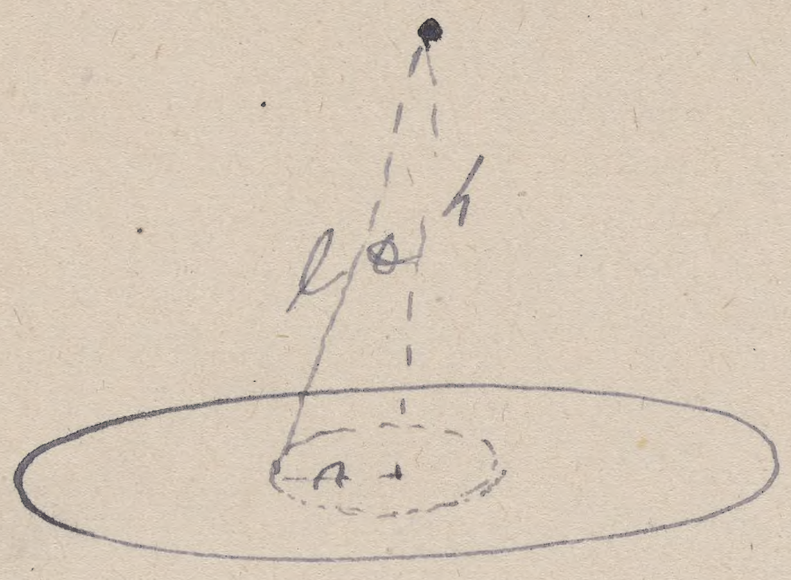



$\rho$ = density

Cut a ring at distance r from center, and suppose of ring

$2\pi r dr$.

and mass of ring

$2\pi\rho r dr$

and this ring is very distant

l from the unit mass.

$$f = \frac{gg'}{l^2}$$

$$= \frac{2\pi r \rho dr}{l^2}$$

The force of attraction of the ring upon particle.

Expressing this in terms of $\theta$ and $h$ we have

$$\frac{2\pi r \rho\, ds}{h^2 \sec^2\theta}$$

the horizontal component of
this force balance and we
have only the vertical to take
account of.

$$\text{Vert. comp} = \frac{2\pi r \rho \cos\theta\, dr}{h^2 \sec^2\theta}.$$

and total attraction of disc

$$\int_0^R \frac{2\pi\rho \cos\theta\, dr}{h^2 \sec^2\theta}.$$

But we have.

$$r = h \tan\theta.$$

$$dr = \frac{h}{\cos^2\theta}\, d\theta.$$

$R$ substituting above

$$\int_0^\theta 2\pi\rho \sin\theta\, d\theta.$$

$$= 2\pi\rho \int_0^\theta \sin\theta\, d\theta$$

Integrating between limits

we have

$$2\pi\sigma^2(1-\cos\theta)$$

and thus is the attraction of the disc upon the particle.

The attraction of a disc upon a particle on its surface is, we see

$$2\pi\sigma.$$

and thus is independent of the radius of the disc.

# Attraction of a hollow spherical shell

$S$ = element of surface

$\rho$ = surface density.

$\frac{S \rho m}{r^2}$ = attraction on $m$ of $S$

$\frac{S' \rho m}{r'^2}$ = " " " $S'$

Call the 2 cross sections $S'$ and $S''$. Then

$\frac{S'}{\cos \theta} = S$ $\qquad$ $\frac{S''}{\cos \theta} = S''$

but $\frac{S'}{r'^2} = \frac{S''}{r''^2}$

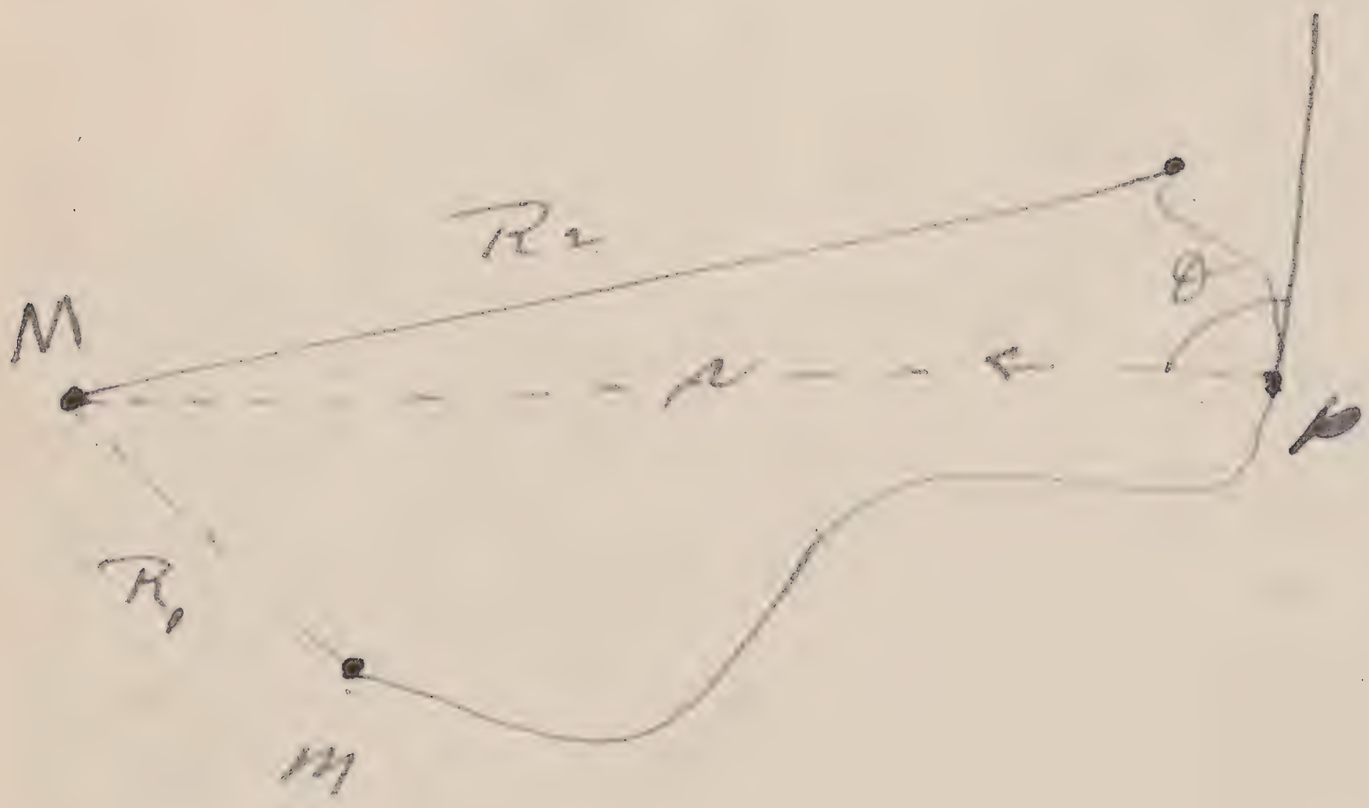
$$\frac{S}{r^2} = \frac{S'}{r'^2}$$

whence we have

$$\frac{S \cdot m}{r^2} = \frac{S' \cdot m}{r'^2}$$

and as you can divide
the sphere of unit a number
of beams of theorem 5 elements
whose force is equal, but
in different directions as above,
hence there is no attraction
of a hollow spherical shell -

To calculate the amount of work in carrying a particle from one point to another.




$$\text{Force} = \frac{m M}{r^2}.$$

$$\text{Comp. force} = \frac{m M}{r^2} \cos\theta.$$

And work equals this times the path $\therefore$

$$dW = \frac{m \cdot M}{r^2} \cos\theta \, ds$$

$$-dh = ds \cos\theta.$$

$$\therefore dW = -mM \frac{dh}{r^2}$$

and integrating

$$U = -\int_{R_1}^{R_2} m M \frac{dr}{r^2}$$

$$= m M \left(\frac{1}{R_2} - \frac{1}{R_1}\right)$$

and this depends only upon

$R_1$ and $R_2$

before had taken it

to infinity, where $R_2 = \infty$, then

$$U_{R_2 \infty} = -\frac{m M}{R_1}$$

If we make the attracted mass

unity, then the result we define

as the Potential, denoted by

$V$.

$$V = -\frac{M}{R_1}$$

wh. is the work done in
bringing a particle from ∞
to R, against force of attraction
of M.

Let us have _ _ _
attracting systems to find the
potential at any point.

$m_3$

$$V = -\left(\frac{m_1}{r_1} + \frac{m_2}{r_{II}} + \frac{m_3}{r_{III}} + etc\right)$$

The potential at any point is the work done by the system upon the body in carrying it from the point to an infinite distance.

$$V = - \sum \frac{m}{r}$$

If a body move from a point where potential is $V_1$ to where potential is $V_2$: then the work done upon the body is

$$m(V_1 - V_2)$$

and the kinetic energy is increased, or

$$m(V_1 - V_2) = \tfrac{1}{2} m(v_2^2 - v_1^2)$$

$$m V_1 + \tfrac{1}{2} m v_1^2 = m V_2 + \tfrac{1}{2} m v_2^2 = C$$

And this equation expresses the law that the sum of the potential energy and kinetic energy is constant.

## Force

Work is equal to force times distance

$$F.d = W = V_1 - V_2$$

$$F = \frac{V_1 - V_2}{d}$$

and hence rate of $V_1 - V_2$ to d, is the force acting upon unit mass at point (1)

$$F = \frac{dV}{ds}$$

from this potential we can
very easily calculate the
force.

Example.

$$V = -\frac{m}{r}$$

and force in direction of m.

$$\frac{dV}{dr} = \frac{m}{r^2}$$

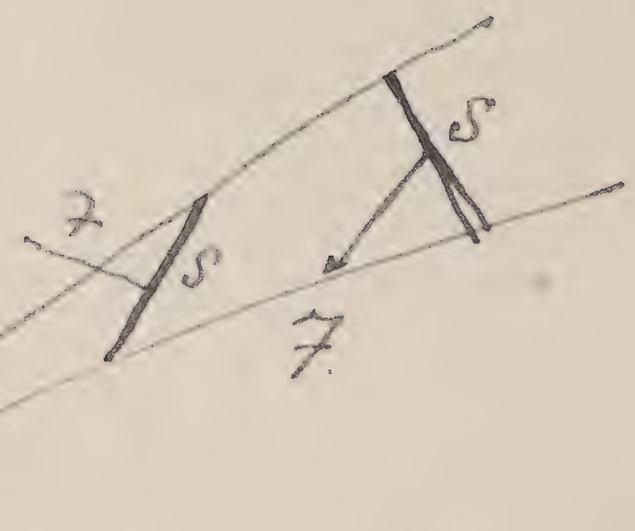
again to find force in
direction at right angles to it.

$$\frac{dV}{ds} = 0$$

there is no force in
this direction.

Equipotential surfaces and lines of force — The more rapid the change in potential the greater the intensity of the resultant force — If the equi. surfaces be drawn at potentials differing by unity, then where they are closer together, the force is greater. The lines of force are every where perpendicular to the equipotential surfaces.

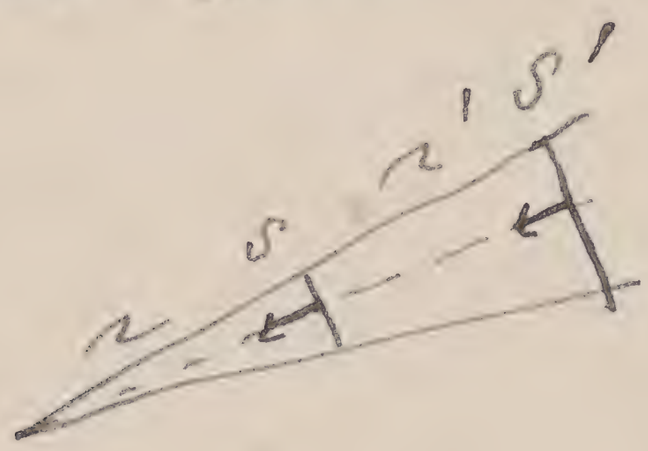
A tube of force is a region bounded by lines of force —




$FS$ = constant

where $F$ is the component force normal to element of surface

$S$. If we have this




$$\frac{S}{r^2} = \frac{S'}{r'^2}$$

and for force

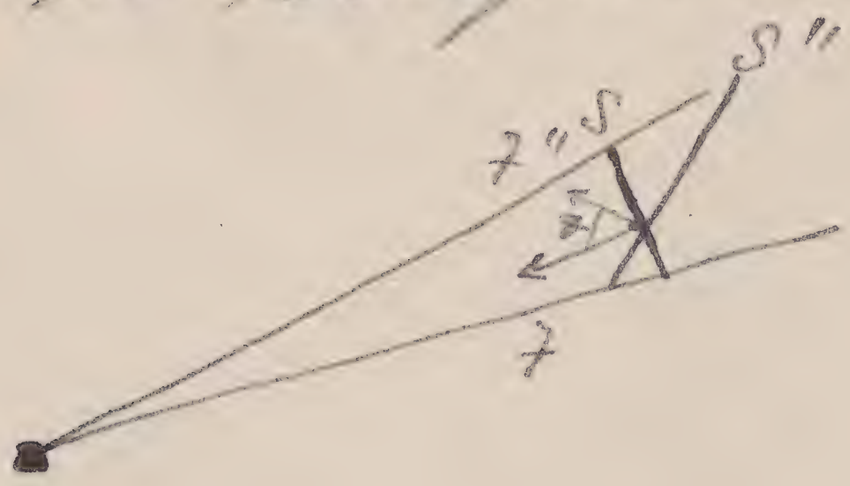
$$F = \frac{m}{r^2}, \quad F' = \frac{m}{r'^2}$$

$$F_S = \frac{mS}{r^2} \qquad F_{S'} = \frac{mS'}{r'^2}$$

$$\therefore F_S = F_{S'} = \text{const.}$$

when the surface is at right angles to line of force

to show it surfaces inclined at




$$S = S'' \cos\theta.$$

Compound force in direction

$T''$, $T = T'' \cos\theta$.

whence.

$$S T = S'' T''$$

Then what we have just
shown.

$$7s = 7's'$$

and calling force directed
inward as positive, we would
have,

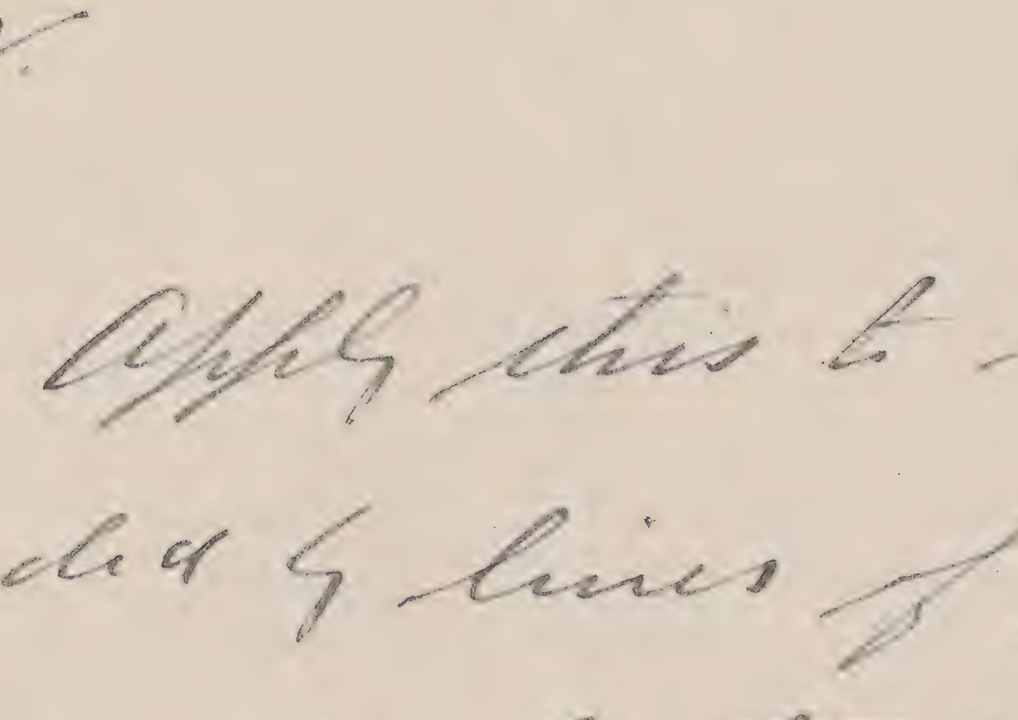
$$7s = -7's'$$

or $7s + 7's' = 0$.

And as surface may be
divided up into such pairs
of surfaces, we may say
the surface integral of the

normal force measured
outward, but a parallel
outside of the closed surface
is equal to 0. And this
may be generalized to the
to any system of attracting
bodies.

Apply this to a region
bounded by lines of force and
two equipotential surfaces




but we know that there is no
force normal to lines of force,
hence the sum of the outgoing
or in ends must be 0

$$\int F ds + \int F \delta s' = 0$$

(b) Find the potential of a circular plate at a point situated on a line thro' its centre ⊥ to its plane

(ii) Find the attraction of the plate on the point, from the potential

iii Find the potential of a circular annulus, at its centre

iv Potential of finite rod at centre

v Potential of circular rects at its centre

vi Potential of cone at its apex

Answers to problems.

1. $2\pi ph\left(\frac{1}{\cos\theta} - 1\right)$

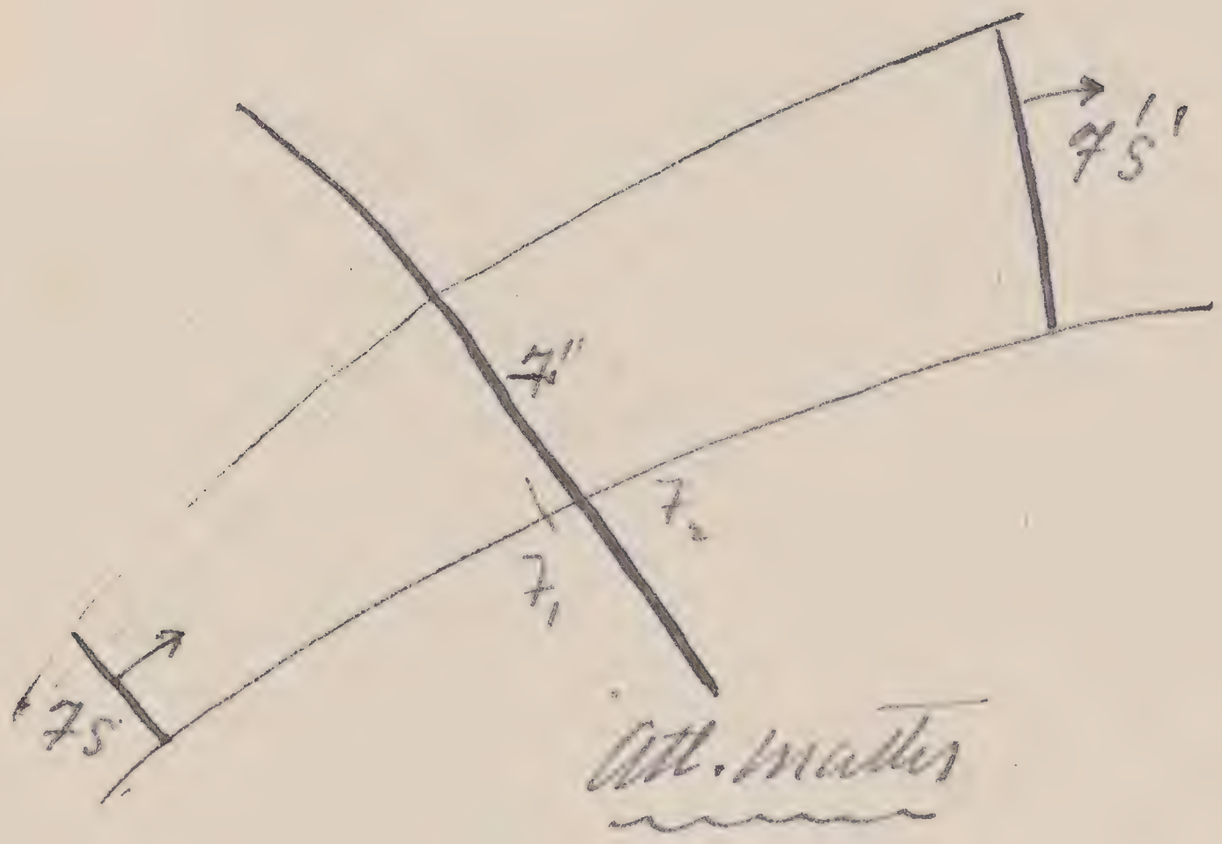
2. $2\pi ph(1 - \cos\theta)$

3. $2\pi ah$

4. $2\pi a(h_1 - h_2)$

5. $\pi OR$.

6. $\pi ph^2\left(\frac{1}{\cos\theta} - 1\right)$




The sum of these forces through a layer of attracting matter then are the lines of force while the attracting matter is there

$F_S$ is constant in region below the attracting matter, and $F_{S'}$ is the region above.

The force on a particle near the matter is $2\pi\rho$ and the actual force just below this surface with k

$$F_1 = F'' - 2\pi\rho$$

and the force just above

$$F_2 = F'' + 2\pi\rho.$$

where $F''$ is the force that would be at this point due only to that space.

$$F_2 - F_1 = 4\pi\rho.$$

$$\therefore \quad F_2 S'' - F_1 S'' = 4\pi\rho S''$$

But $F_2 S'' = F' S'$

$$F_1 S'' = F S$$

$$\therefore \quad F' S' - F S = 4\pi\rho S'' = 4\pi q.$$

for $\rho S''$ is the total quantity of matter in the surface, or the whole space.

Laws of Elec. Action

The total electrification of a system remains unchanged except by addition

The total electric - remains the same after redistribution by conduction.

Equal quantities of + and - electr are always produced

If an electrified system is placed inside a closed conducting surface, the inner elec. is equal and opposed to the electrons of the system.

If an electrified body is
inside of the closed body, the
elec. of the surface is zero
at every point.

The free excess is
the product of the quantities
and measured as the
square of the distance

the law and gravity of

electrons such that

$$F = \frac{gg'}{r^2}$$

Experiment only shows that

there are surfaces, bounding

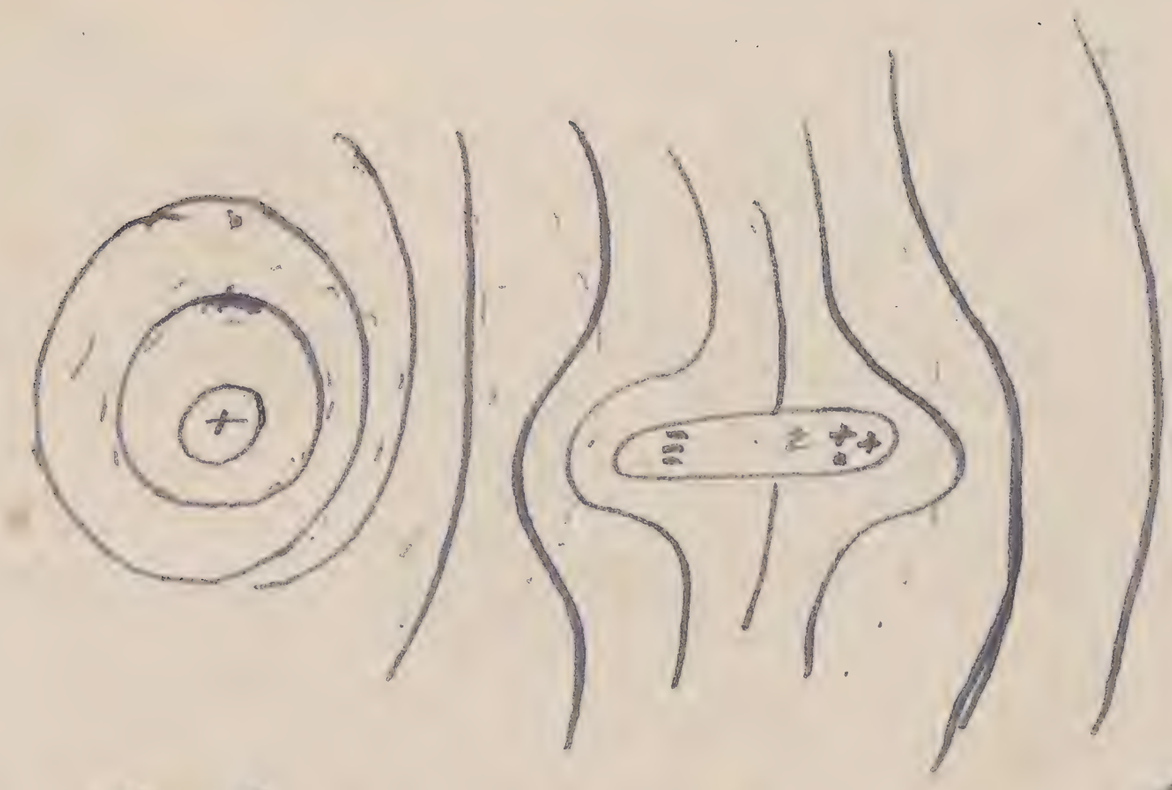
them equal, we define

unit of electricity.

The density is gravity

per unit surface.

On the surface over
which the rays of the conductor
the potential is constant. In
the electric is free & move and
if there were a diff. in potential
free would be exerted and
a flow of electricity would
result until the potential
was the same at every point
(conductor) surfaces are
hyperpotential surfaces whether
the charge be free or induced.



If body (2) were not present the equipotential surfaces would be circles. When (2) is present if the surfaces remained circles one end would be of higher potential than the other, but this is impossible. The surfaces will be distorted by body (2) and take shape in figure.

# Prob.

Given - the steps of two lines when inclined to one another & of intersection - to calculate the Radius of Circle and the Number of Steps.

This is Solution of narrow
circular annulus, of th centre
$(2\pi\rho dy)$

Of a fluid mass
$2\pi\rho(R-R_0)$

Sides of th centre
$\rho R_0$

Cone at apex
Vol $\frac{\pi\rho R^2}{3}$

Dem C
Prof Sidney

The electrical force just
outside a conductor of charge
$\sigma$ is $4\pi\sigma$. There is no
force within the conductor,
$\therefore$ all points have the same
potential. Lines of force
are $\perp$ to surface, and must
end at surface for there is
no force within conductor.
But when a bit of free
charge through a layer of
attracting matter, the charge
on the face is $\sigma$. The
outside surface the face
on both of face is $\sigma$ on
outer surface 0. but

$$\sigma - 0 = 4\pi\sigma$$

$$\therefore \sigma = 4\pi\sigma$$

$$\mathcal{F}_S = \mathcal{F}_{S'}$$

Tube of force enclosing two

enclosing surfaces.

$$\mathcal{F} = 4\pi\omega.$$

and $\mathcal{F}' = -4\pi\omega'$

$$4\pi\omega_S = -4\pi\omega_{S'}$$

$$\omega_S = -\omega_{S'}$$

or $g = -g'$

in the quantity of electricity

in and for tube of force

is equal and opposite for

at other end. Holds only for

places where tube terminates.

If tube starts at + electricity

at ends at same potentials

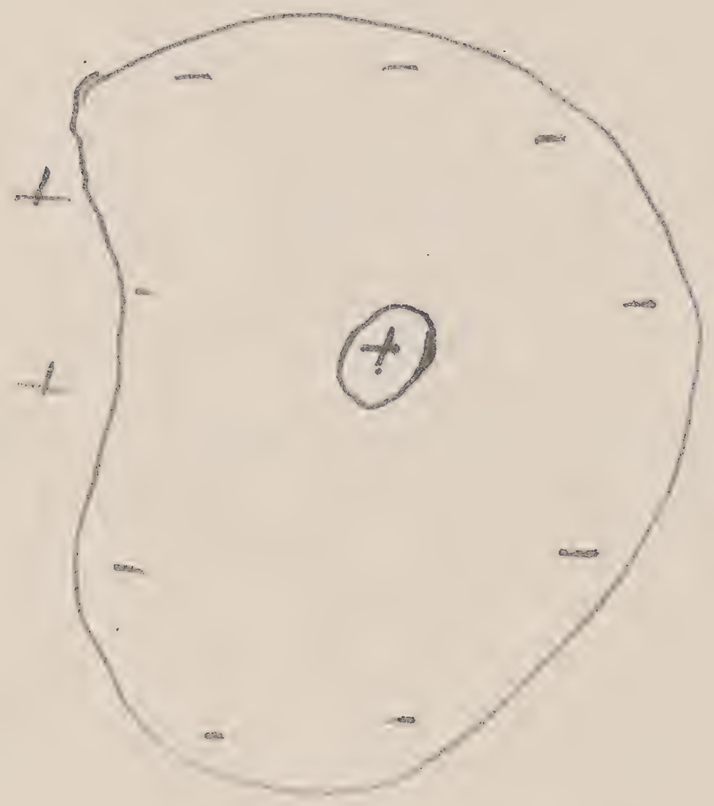
7 — Electricity

A closed conductor with

running charged bodies within

The distribution of electricity
on a closed conductor is the
same as the law of distribution
of gravitation matter that gives
zero force in the interior
lines of force terminate
when the meet on a closed
conductor. If a charged body
is in the interior of a
closed conductor, there is
an equal and opposite induced
charge on the interior. A
charged body inside a closed
conductor will ~~not~~ induce
a charge on a body outside
the surface, not a charged

body would not induce
a charge on the body within



The potential of the earth

is taken as the standard

zero potential. A body

lower potential when connected

with the earth, + vice. flows

from the earth to the body, such

body is said to be negatively

charged. A body is discharged

when at same potential as

the earth.

Free and bound charge.

The charge is free when taken

away from all disturbing

bodies and connected with

the earth, there is a flow of

electricity, until finally

Some circumstances then
in the flow of electricity.

A = free B = bound.

If a closed conducting
surface be encircled with
the earth, there may exist
two systems, no excess and
one entirely neutralizing
of each other.

If any given potential
surface belongs to any
electrical surface be drawn
and on that surface electricity
be distributed in such a

manner that the density

at every point, $\rho = \frac{I'}{4\pi}$, then

the surface is absorbed

with exactly replace the

system for all bruits

outside the surface.

This is only one distribution

of the, we a closed conductor

surface. But there be two

but not the surface, a

certain quantity according

to this formula, and an

equal quantity according

to the second. If the two

bodies be not exactly like

this will at some points

an excess of +, at others an excess of −. but generally & regularly etc. cannot not be free distributed over a conductor, they must neutralize at very short distances. The lines of force must be at right angles to the surface always. Surface at any point is proportional to the quantity of elec. on it contains. The potential of a body is directly proportional to the quantity of electricity put

upon it. We may define the capacity of a conductor. named from all other conductors, wh. is caused from 0 to potential V by q. quantity Coulc. & let equation

$$q = CV.$$

$$C = \frac{q}{V}.$$

in the quantity of elec. wh. must be put on body to raise it from potential 0 to 1

For a sphere the capacity varies as the radius.

We have used

$$F = \frac{qq'}{r^2}$$

but the force varies when the electrified bodies are separated by different media. For vacuum the law is true, for all media the force is less and our formula is

$$F = \frac{1}{K} \cdot \frac{qq'}{r^2}$$

K = the specific inductive capacity: for air and gases K is very nearly unity.

The potentials are

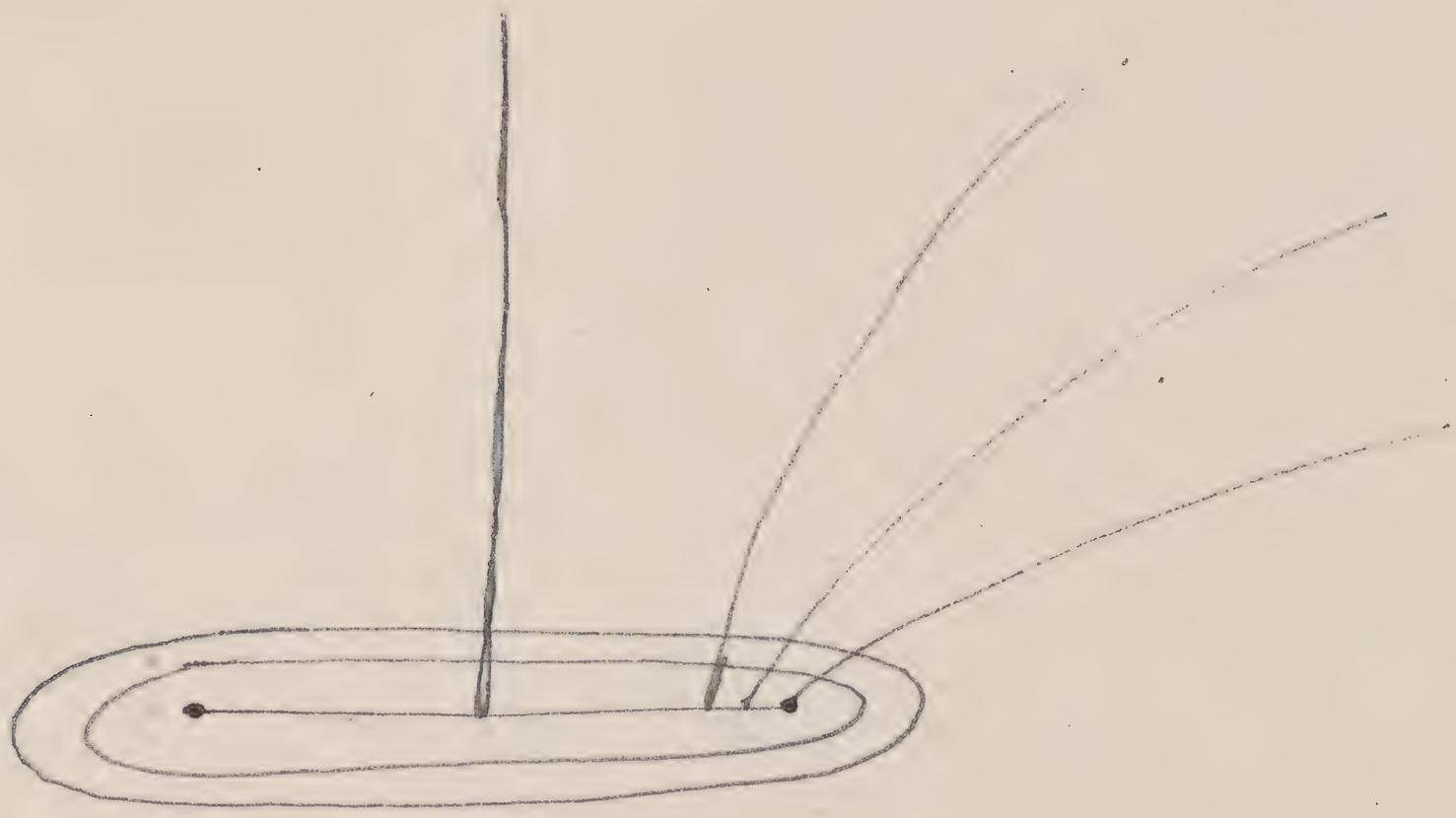
reciprocal capacity

$$\frac{k'}{v} = \frac{1}{k}$$

Again

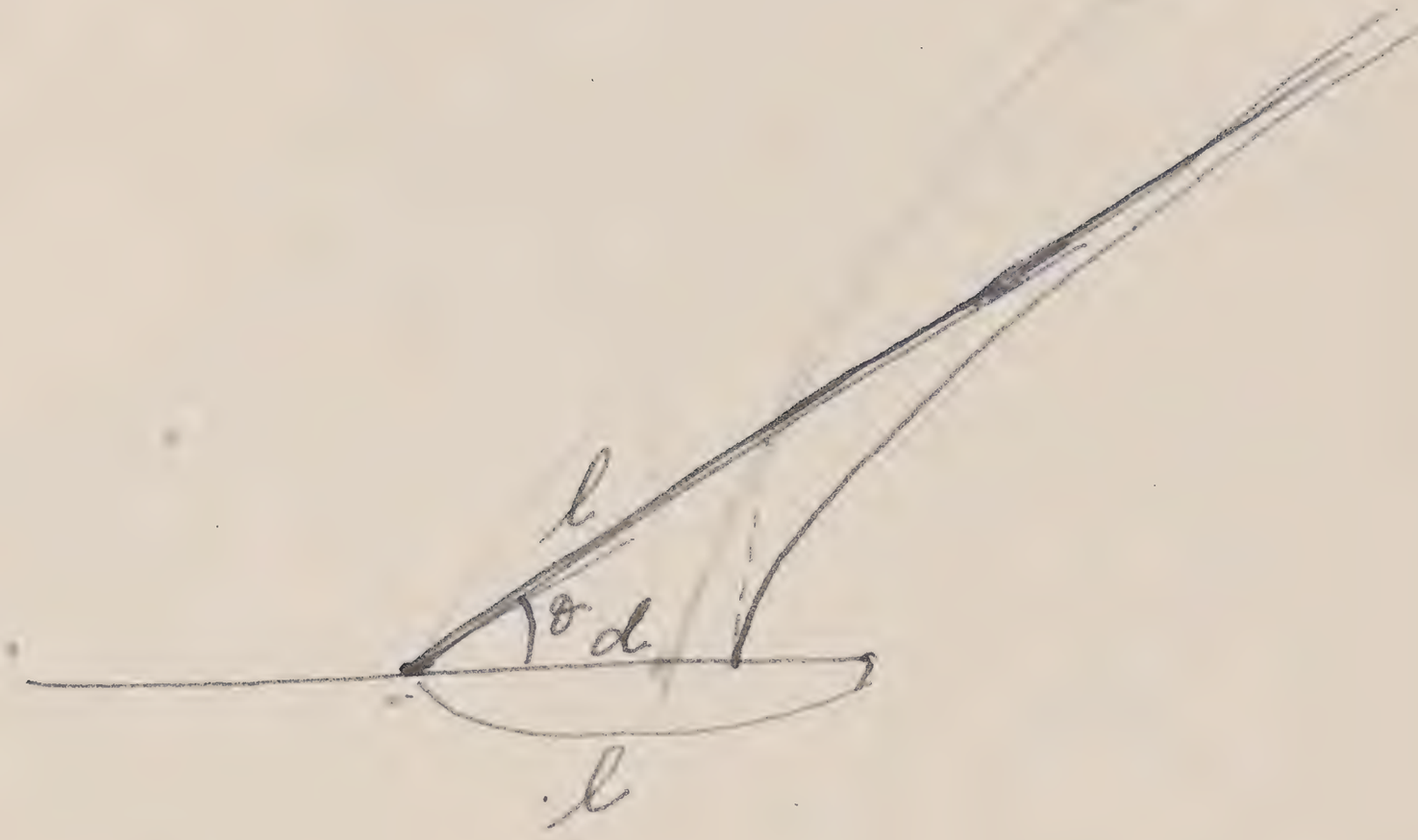
$$\frac{g}{g'} = \frac{1}{k}$$

Illustration of tube in a vessel



The quantities on the two sides of a tube of free are equal. On the infinite plane the distribution is uniform.

But we have from the hydrostatics of an hydrula




$l \cos\theta = d.$

$l = \frac{1}{2}$ length of line $= \text{const.}$

$-l \sin\theta d\theta = d.d$

$-l \sin\theta = \frac{d.d}{d\theta}.$

area of zone on surface of sphere

$= R\, d\theta.$

radius of zone $= R \sin\theta$

area " " on sphere $= 2\pi R \sin\theta\, R\, d\theta.$

" " whole " $= 4\pi R^2$

The ratio of quantity in whole
sphere and in this zone is
same as in whole line to
that part of line we are
dealing with, same as
ratio of area of whole sphere
to area of zone.

$$\frac{Q}{\rho\, d.d} = \frac{4\pi R^2}{2\pi R^2 \sin\theta d\theta}$$

$$\rho = \frac{Q \sin\theta}{2} \cdot \frac{d\theta}{dl}.$$

$$= \frac{Q}{2l}$$

$\rho$ = quantity per unit length

$Q$ = " in whole wire.

By rotating the line about
a vertical axis through its
middle point, we could ob
a similar way find the
distribution in a circular
disc

# Specific Inductive Capacity

Air 1.00059

$CO_2$ 1.00096

H 1.00026

Cl 1.00069

Br 1.00094

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Ebonite = 3.15

Paraffin = 2.32

Sulphur 3.84

To determine the specific inductive capacity we have

$$K = \frac{QQ'}{r^2} \cdot \frac{1}{F}$$

where we have

$$\frac{V'}{V} = \frac{1}{K}$$

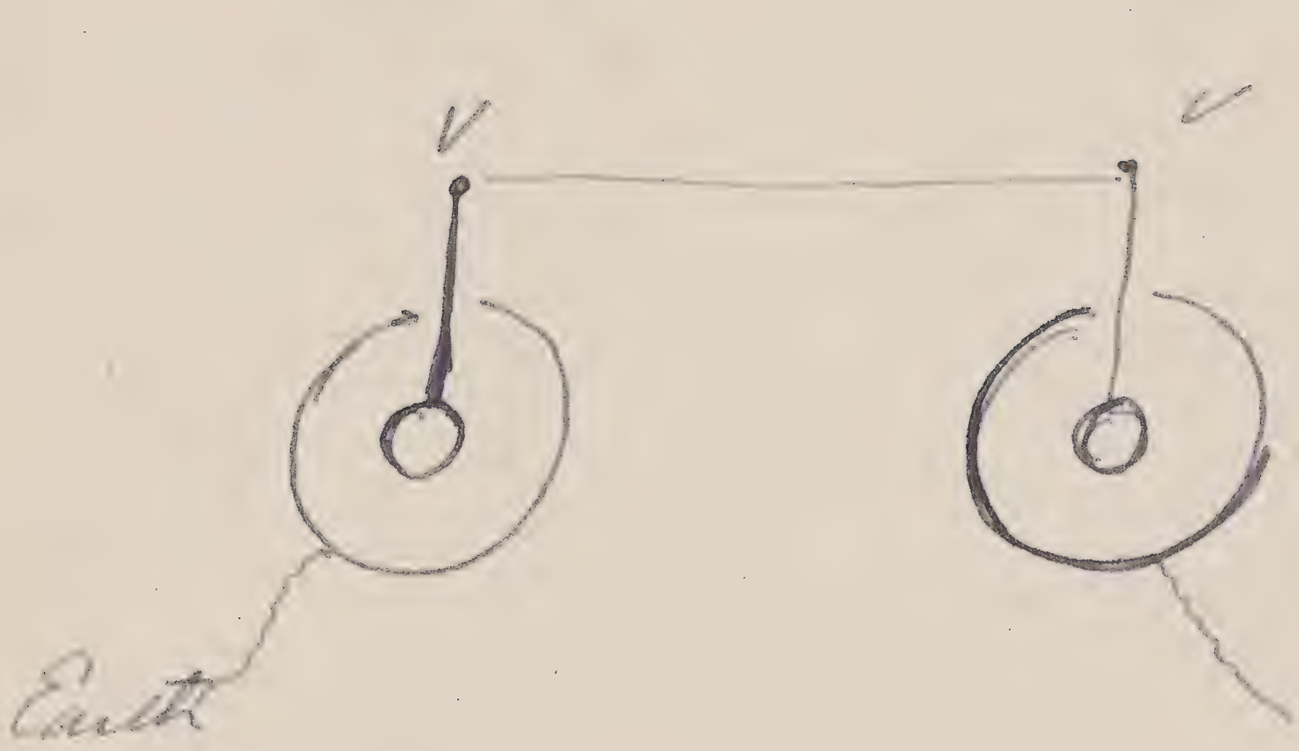
$$\frac{C}{C'} = \frac{1}{K}$$

Faraday's method.

He enclosed a sphere

in another sphere; making

a spherical condenser.



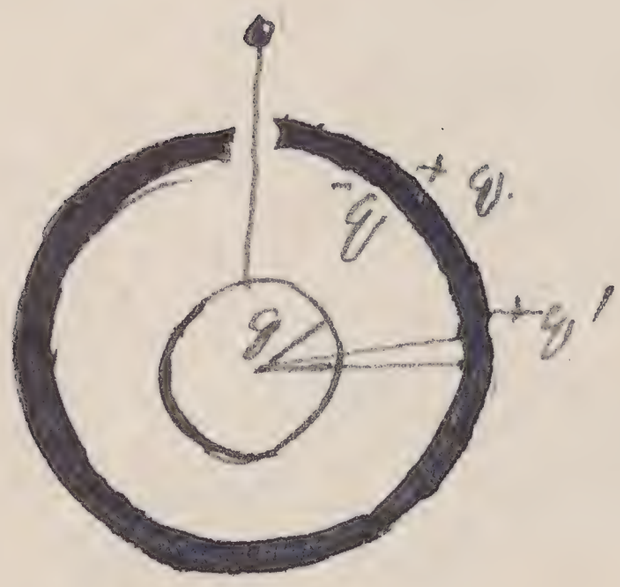
$$S = VC$$

$$= V'C + V'CK$$

$$\therefore K = \frac{V - V'}{V'}$$

The capacity of two unequal

spheres.




$q$ = quantity of elec. on inner sphere

$q'$ = " " " " outer "

$r_1$ = radius of small sphere

$r_{11}$ = " " inner surface of large

$r_{111}$ = " " outer "

$$V_c = \frac{q}{r_1} - \frac{q}{r_2} + \frac{q+q'}{r_3}$$

the expression for the potential

at the center: and this

is the potential of the inner

conductor.

The potential of the outer conductor is that of a point unit charge at the outer surface: and the sum of the elec. and Coulomb's value at the center

$$V_0 = \frac{q - q + q + q'}{r_3} = \frac{q + q'}{r_3}$$

The difference of potentials is

$$V - V_0 = \frac{q}{r_1} - \frac{q}{r_2}$$

and this expression is independent of the charge of the outer sphere.

When $V - V_0 = 1$, the conductivity value of $q$, is the capacity.

$$C = \frac{1}{\frac{1}{r_1} - \frac{1}{r_2}} = \frac{r_1 r_2}{r_2 - r_1}$$

When the medium between

the two conductors is changed

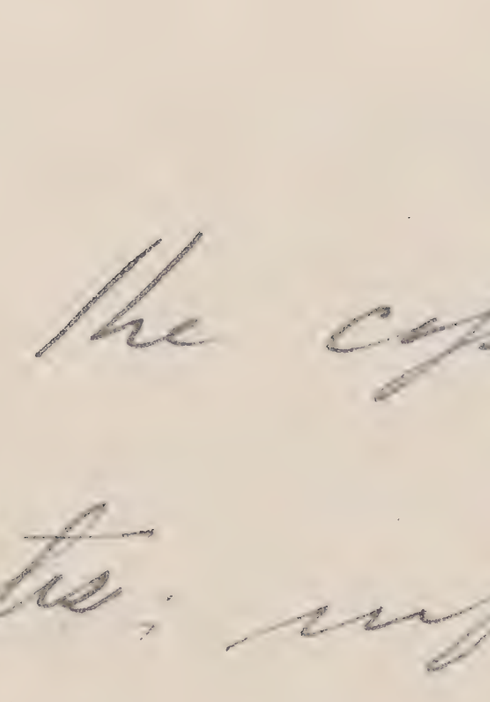
from one with S. C. C. = k. then

we have

$$C = \frac{n_1 n_2}{n_2 - n_1} k$$

the capacity of two parallel

plates, infinite in extent.



The lines of force

are cylinders, the

lines of force at

ends. Eg. Sol. surfaces

planes

Now we have

$F_2 = \text{const}$

but as tubes or cylinders

S - cont.

$\therefore \quad f = \quad "$

$$-\frac{dl}{dr} = \frac{V_1 - V_2}{d} = f$$

but the force per unit

the surface of the tube is

$4\pi\sigma$

$\therefore \quad f = 4\pi\sigma$

Let $dS$ be the area of the

surface whose capacity we

are to calculate.

$$\frac{V_1 - V_2}{d} dS = 4\pi q.$$

whence for the capacity

$$\frac{S}{d} = 4\pi C.$$

$$C = \frac{S}{4\pi d}$$

and for a different medium

$$C = \frac{S^2 K}{4\pi d}$$

On the assumption that

the sphere is the first case

are unfruitful due to the

this second case applies

and gives the result obtained

in first consideration.

If the planes be limited

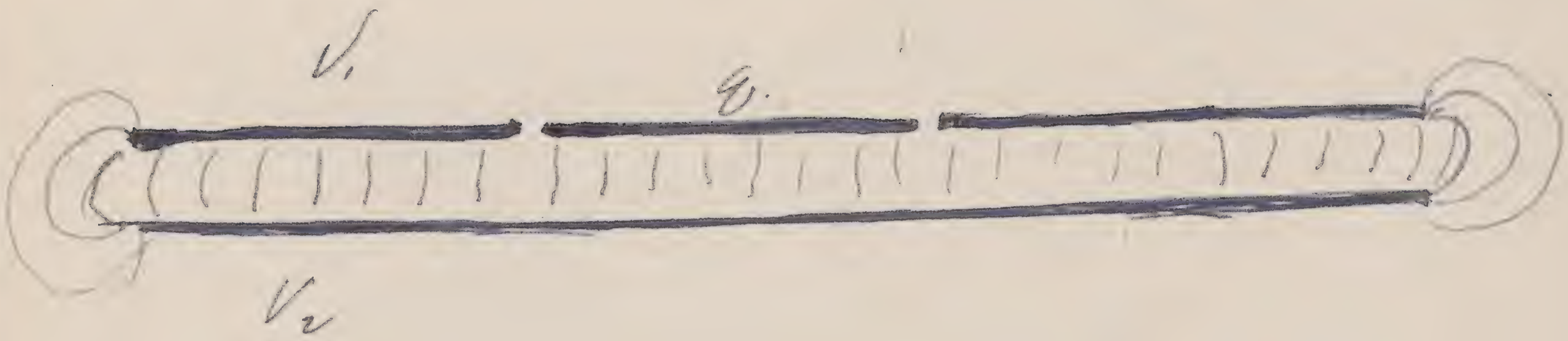
the lines of force are no

longer straight lines, and my

formula will not apply.

By the use of the guard

may we get on this difficulty




To measure difference of potentials, we measure the attraction of unlike points in the same.

$$\frac{V_1 \quad S}{\frac{1}{d}}$$
$$V_2 \quad S$$

the same

$$\frac{V_1 - V_2}{d} = 4\pi\rho.$$

the force, and an unit of area, this is a quantity of electricity, & hence

$2\pi\rho^2 =$ Attraction $= P$

due to charge.

$$P = \frac{2\pi (V_1 - V_2)^2}{16\pi^2 d^2}$$

$$= \frac{(V_1 - V_2)^2}{8\pi d^2}$$

the force of attraction per
unit area, and the distance

$$P = \frac{S (V_1 - V_2)^2}{8\pi d^2}$$

the gives a means of calculating
the difference of potential

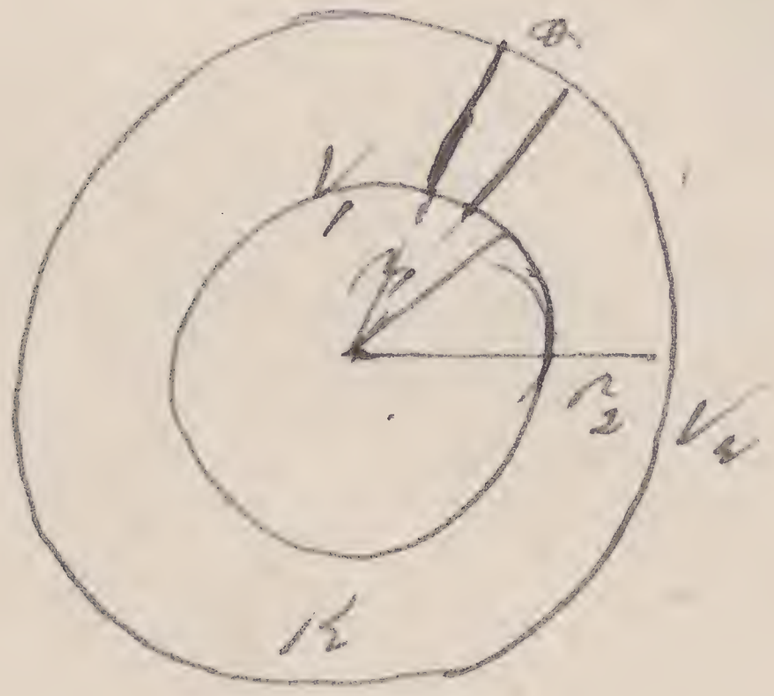
$$V_1 - V_2 = d \sqrt{\frac{8\pi P}{S}}$$

If we measure P by weighing
then

$$P = kg.$$

expressed in dynes.

Capacity of two concentric cylinders




Lines of force will be radii, and equipotential surfaces will be concentric cylinders.

$S = r\theta L$ $\quad Z_S$ = const. for tube of force

$Z = -\frac{dV}{dr} \quad -\frac{dV}{dr} r\theta L = \text{const.} = Z_S$

integrating around the cylinder $\theta$ becomes $2\pi$

$$-\frac{dV}{dr} 2\pi r L = C$$

integrating between the limits $V_1, V_2$, and $r_1, r_2$.

$$(V_1 - V_2) 2\pi L = C \log \frac{r_2}{r_1}$$

Let $\rho$ be the surface density of unit cylinder: then

$$4\pi\rho$$

is the surface

$$4\pi\rho \cdot 2\pi r_1 l = C.$$

Substituting in former equation

we have

$$V_1 - V_2 = \frac{C}{2\pi r_1 l} \log \frac{r_2}{r_1}$$

The quantity of elec. on unit length.

$$q = 2\pi r_1 l \rho$$

$$\therefore 2\pi\rho = \frac{q}{r_1 l}$$

and substituting above.

$$V_1 - V_2 = \log \frac{r_2}{r_1} \cdot \frac{2q}{l}$$

$$g = \frac{L(V_1 - V_2)}{2 \log \frac{r_2}{r_1}}$$

but the capacity is the

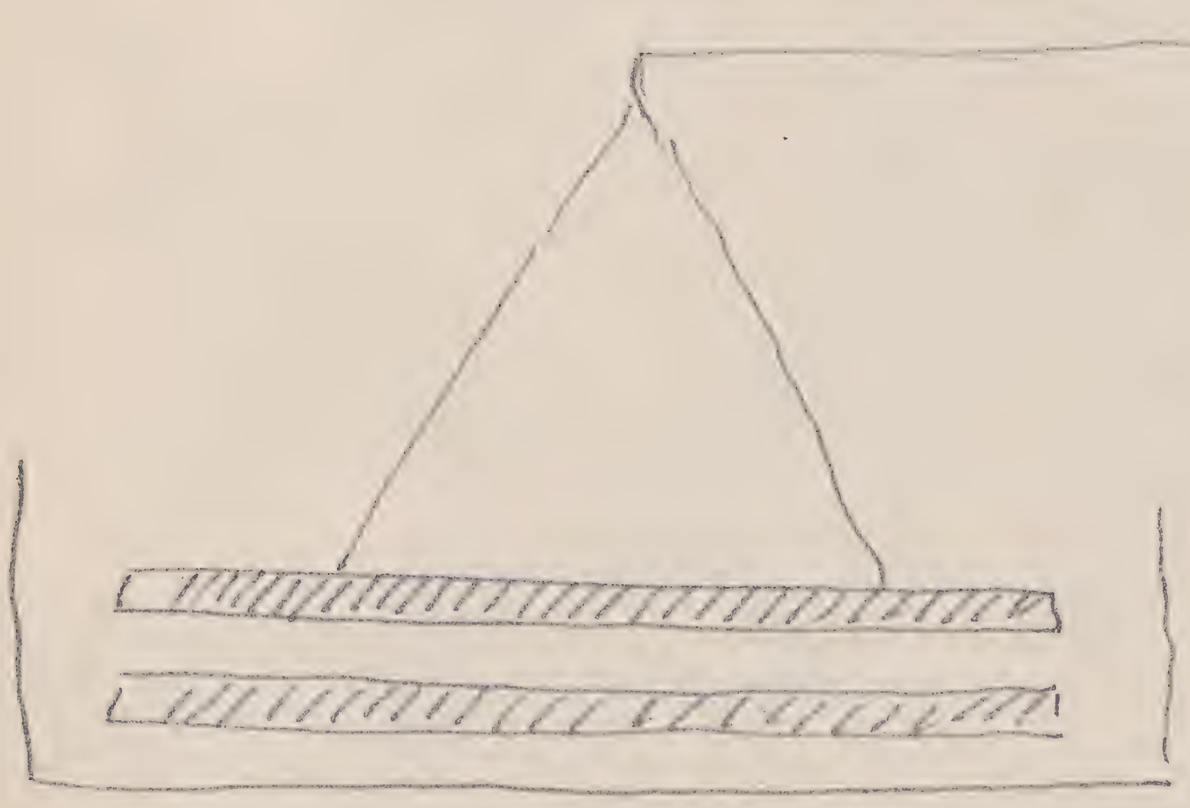
quantity when $V_1 - V_2 = unity$

$$\therefore C = \frac{L}{2 \log \frac{r_2}{r_1}}$$

and for any other medium

$$C' = \frac{CK}{2 \log \frac{r_2}{r_1}}$$

Lecture experiments (Weidemann Chs.)
'86



The free pathaction
encountered when air is the
medium: than when some
thing else is used.

$$P = \frac{K_1 V_1 S}{\delta \pi \delta^2}$$

$$\frac{K_1}{K_2} = \frac{P_1 V_2}{P_2 V_1}$$

Again be determined K
by measuring the capacities

$$\varphi = CV/L$$

$$\varphi_2 = CV$$

$$K = \frac{\varphi}{\varphi_2}$$

The quantities $\varphi$ are measured by the flux of a galvanometer.

So a medium whose specific

inductive is unity, the tube

Force and tubes of induction

are the same. But when K

differs from unity,

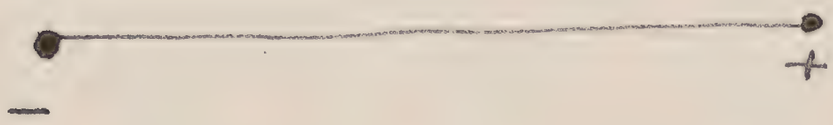
$$= K \frac{dH}{dx}.$$

When the condenser discharges

the discharge is not instantaneous

but oscillatory. Each condenser

has a time constant.




When these fronts are connected

by electrolytes such to guttie, but

to illustrate from mechanics, they

do not at once come to rest, but

oscillate about the central point.

In case of condensers of

glass etc. we have what is

called the residual discharge.

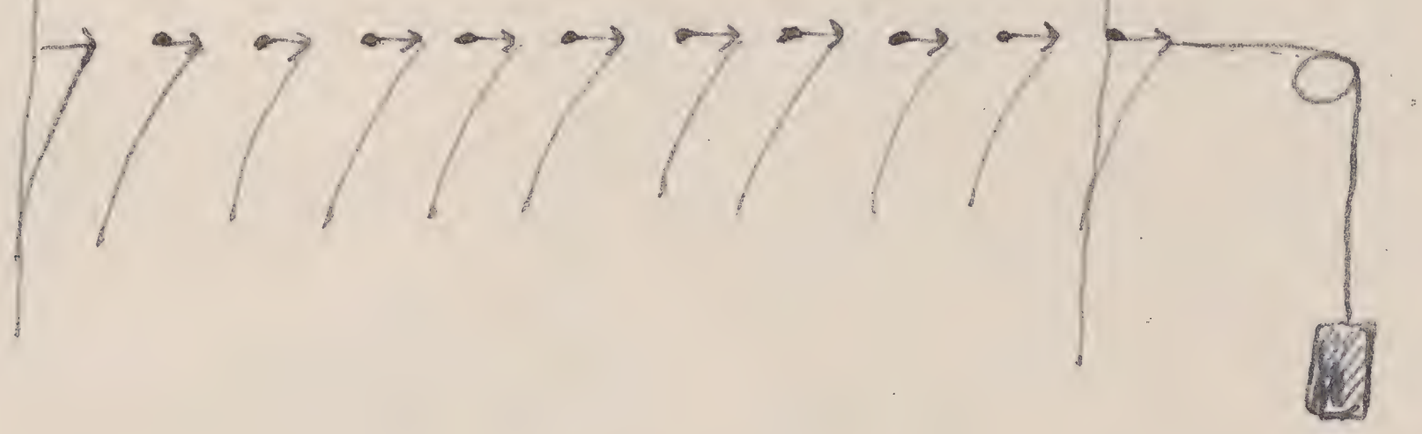
This is not thought of as like

hesitating with the glass. But

more as any electrical

displacement. if the

charlecty be keyfed we will
here no residual discharge



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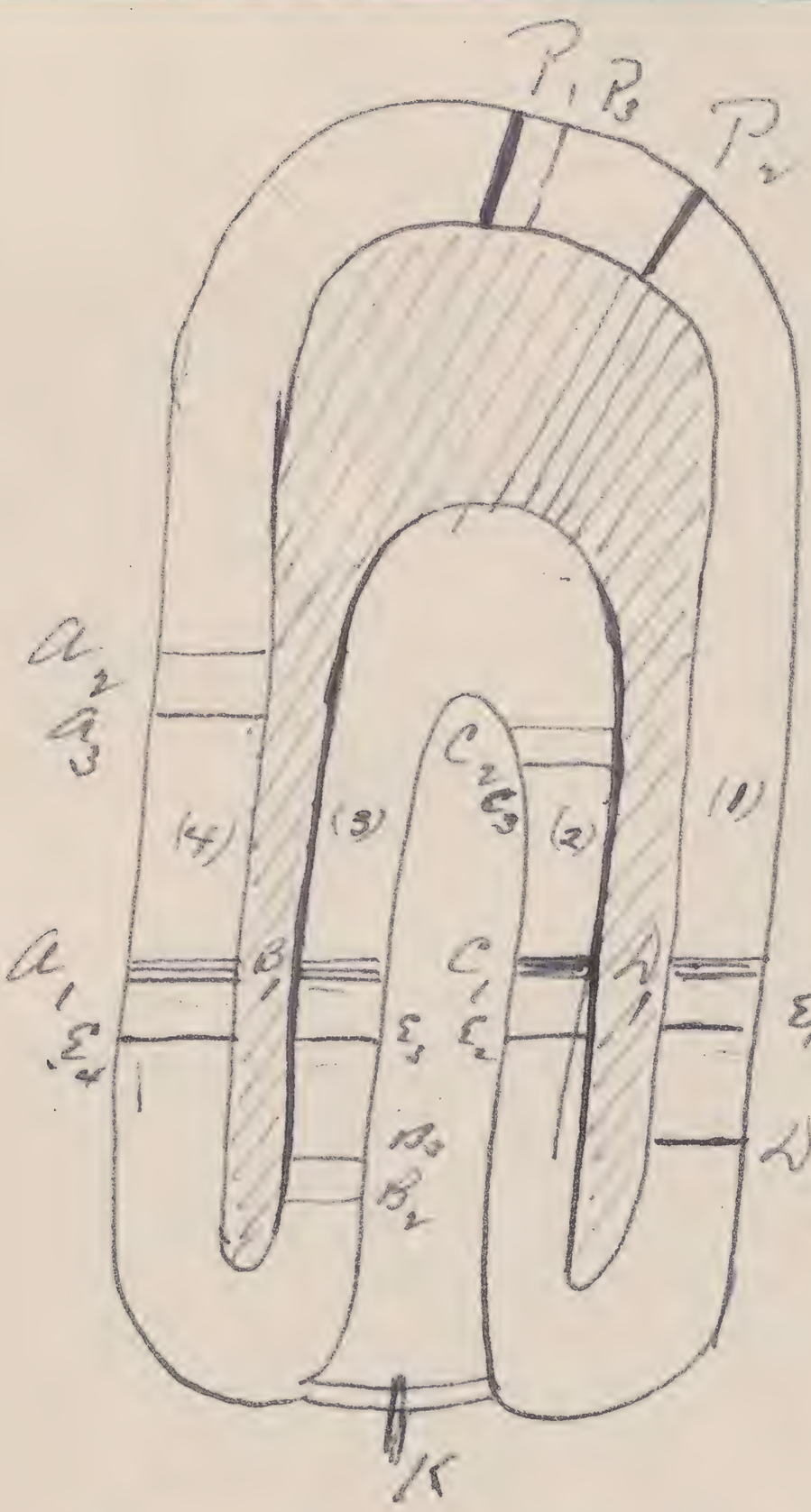



Mercury below
line a, b, c, d,
Water fills the
remainder of
tube
$P_1$ = pressure on
pit pressure

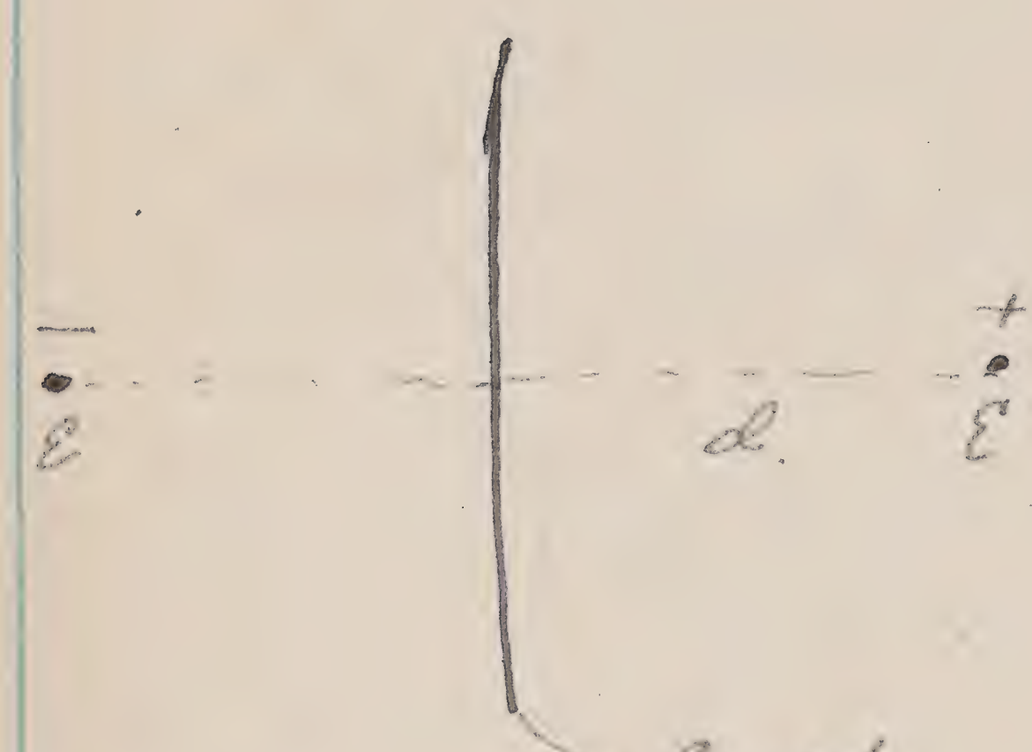
If this pressure be exerted to pressure
E, the water in tube D will be forced
down and surfaces of separation of
water and mercury will be in
$D_2$. $C_2$. $B_2$. $A_2$: If now the pressure be
free to move, the pressure of the
mercury in tubes (2) & (4) will cause
the system to resume its position
of equilibrium (position no 1).

But when the pressure is at $P_2$,
turn the cock L and let in
little mercury flow out, $D_2$ will

remain stationary, but $A_2$, $B_2$, $C_2$ will take the positions $A_3$, $B_3$, $C_3$. On being fired the system will be in equilibrium in $E_3$, $E_1$, $E_2$, $E_3$, $E_4$ — That is if there be leakage the discharge will not be perfect.

# Electric Images

See Maxwell and notes thereon




A plane, and a charged point, to find the distribution on the plane.

Place behind the plane a charged point — and at equal distance. And potential of plane due to these points is

$$V = \frac{\varepsilon}{r} - \frac{\varepsilon}{r} = 0$$

at the same as when only the point and plane connected to earth.

Hits on electric images are not
full for Stern first and Maxwell
on that point.

7. I find the distribution of
electricity over a conductor. Be
find an ellipsoidal surface
due to images et wh. shall
affect. the shape of the conductor

Given the two conductors of potentials $V_1$ & $V_2$ the distance

$$V_1 = \frac{\mathcal{E}_a}{r_1} \qquad V_2 = \frac{\mathcal{E}_b}{r_2}$$

the potentials due to the charges of each sphere. But when the body B is placed in proximity it decreases the potential of A, therefore to bring it down to $V_1$ we must place at C, the nucleus of B a quantity of — electricity such that it together with the charge B makes a an equipotential surface of $V_2$ potential.

In same way we find the image of $b$ in $B$, and the images of these images and continue the series.

And of the series is refully convergent.

$$F_f = E_b - E_f + E_h - \text{---}$$

$$F_a = E_a - E_d - E_g \text{ ---} \quad .$$

the total quantity of electricity in each sphere. To find the distribution we must find the resultant force at each point on the surface of the sphere. Then we have

$$4\pi\sigma = 7$$

$$\therefore \sigma = \frac{7}{4\pi}$$

To find the energy of the system.

we have.

$$CV = q.$$

the work

$$\int_0^V V\,dq = \int \frac{q}{C}\,dq = \frac{C^2V^2}{2C}$$

$$= \frac{CV^2}{2} = \frac{qV}{2}$$

the energy is one half the product of the charge and the potential.

The energy of the system.

$$U = \tfrac{1}{2} V_1 E_A + \tfrac{1}{2} V_2 E_B.$$

We have from this

$$-\frac{dW}{dc} = \text{Repulsion}$$

$$+\frac{dW}{dc} = \text{Attraction}$$

# Electricity in Motion

The electro-static system of units may still be used. The defining equations of this system is as we have seen

$$F = \frac{qq'}{r^2} \cdot \frac{1}{K}$$

and for the present we shall use this system.

We can speak of the potential of two poles of a battery. The flow being due to the difference in potential of the two poles

If the medium be a dielectric, then the lines are elec. static lines of force; if however it be a conductor, then the lines are lines of flow, or stream lines. There is no flow across the walls of a tube of flow.

Equipotential surfaces are the same in the one case as the same as in the other.

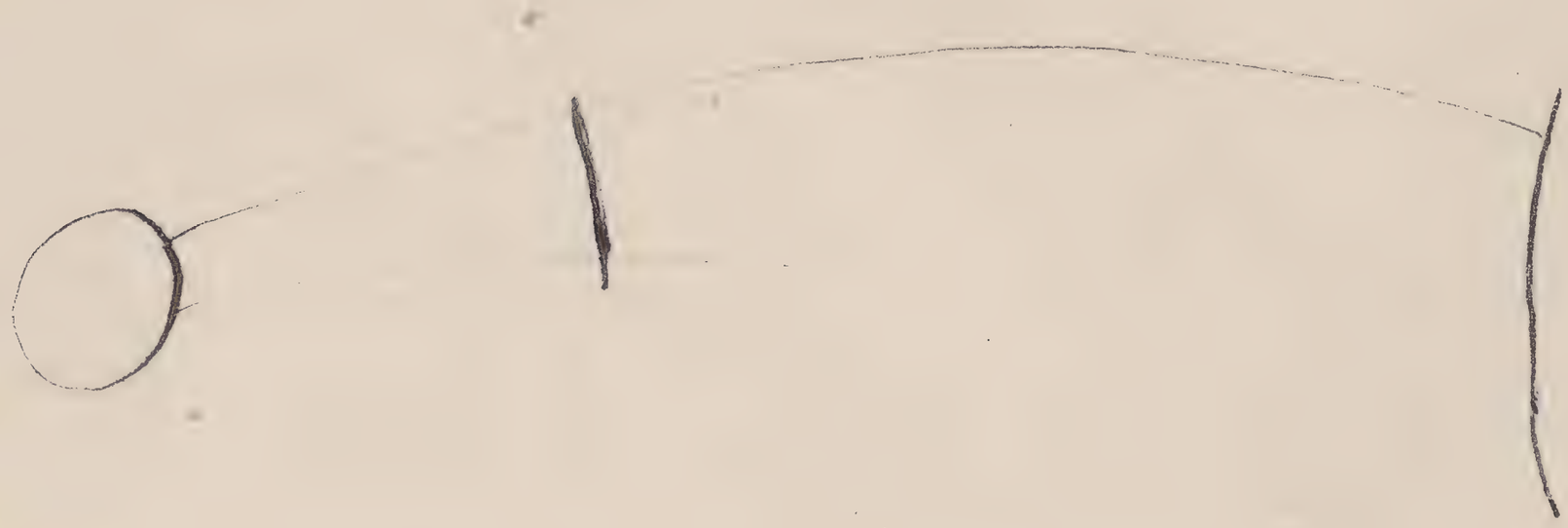
The specific inductive capacity is equal to the specific conductivity.

In the case of fluid flow, in
unsteady flow, how does the
elec. flow as in a long cable
one end of which is suddenly
raised to potential V.

---

During the establishment of
the flow there must be a
charging of the conductor, until
we have steady flow, and then
the stream lines become straight.
When the current is started, the
process is reversed.

# Steady - flow



Take a tube of stream and the quantity of the fluid flowing across any cross section is the same for unit of time. The quantity of the fluid crossing any section per unit of time is the current.

In a tube of force we have

$$F_2 = \text{const.}$$

where $F = -\frac{dV}{dr}$.

The flow depends upon the resistance, to overcome which the quantity stream ...

this across unit area of an equipotential surface when the force has unit intensity. In accordance the flow, by the hypothesis of the unit of charge of electricity.

$$-\frac{dV}{dn}\delta S = \underline{\delta}.$$

The current through the element $\delta S$ and, this expression is constant over the whole of flow.

Take of flow in a cylinder

$S$

Equipotential surfaces are planes, hence Flow II.

$$-\frac{dV}{dx} = \frac{V_1 - V_2}{l}$$

$$\mathcal{F} = \frac{V_1 - V_2}{L} S^c.$$

$$= \frac{V_1 - V_2}{R}$$

$R$ = resistance = $\frac{L}{S^c} = \frac{L}{S} \rho$.

$\frac{S^c}{L}$ = conductivity of the system.

The current

$$I = C(V_1 - V_2) = \frac{V_1 - V_2}{R}.$$

$\rho$ is the specific resistance

The formula for $R$ is known

as Ohm's law. All substances

do not obey this law! All metals,

electrolytic conduction, obey Ohm's

law — But in case of gases it

is not true.

The law may be stated, as the

current proportional to the

electro-motive force.

$R$, or $C$, varies with change

as temperature and pressure. In case of metals the conducting decreases with rise in temperature. Some think that at the absolute zero, the conductivity would be infinite. Whether

Certain substances the conductivity increases with the temperature, carbon, glass, and insulators generally.

The series of metals when arranged in order of electric conductivity is same as when arranged for heat conductivity. The best electric conductors are the best heat conductors.

Arrangement of battery cells,

Cells joined in series, for three cells total difference of potential is three times that of one cell

When joined in parallel circuit, the total difference in potential is the same as for one cell.

For one cell we have.

$$\nabla = \frac{V_1 - V}{n}.$$

For cells joined in series.

Potential = $nV$.

resistance = $nr$.

For cells joined in parallel.

potential = $V$

resistance = $\frac{r}{n}$.

In practice we may arrange the cell 3 in series, and 2 ||.

3 rows, 5 in each row.

Electro. M. F = $5V$.

resistance = $\frac{5r}{3}$.

When the resistance of the external circuit is $R$ we have.

$$A = \frac{pV}{\frac{pr}{q} + R}$$

the current in this arrangement.

$$= \frac{nV}{pr + qR}.$$

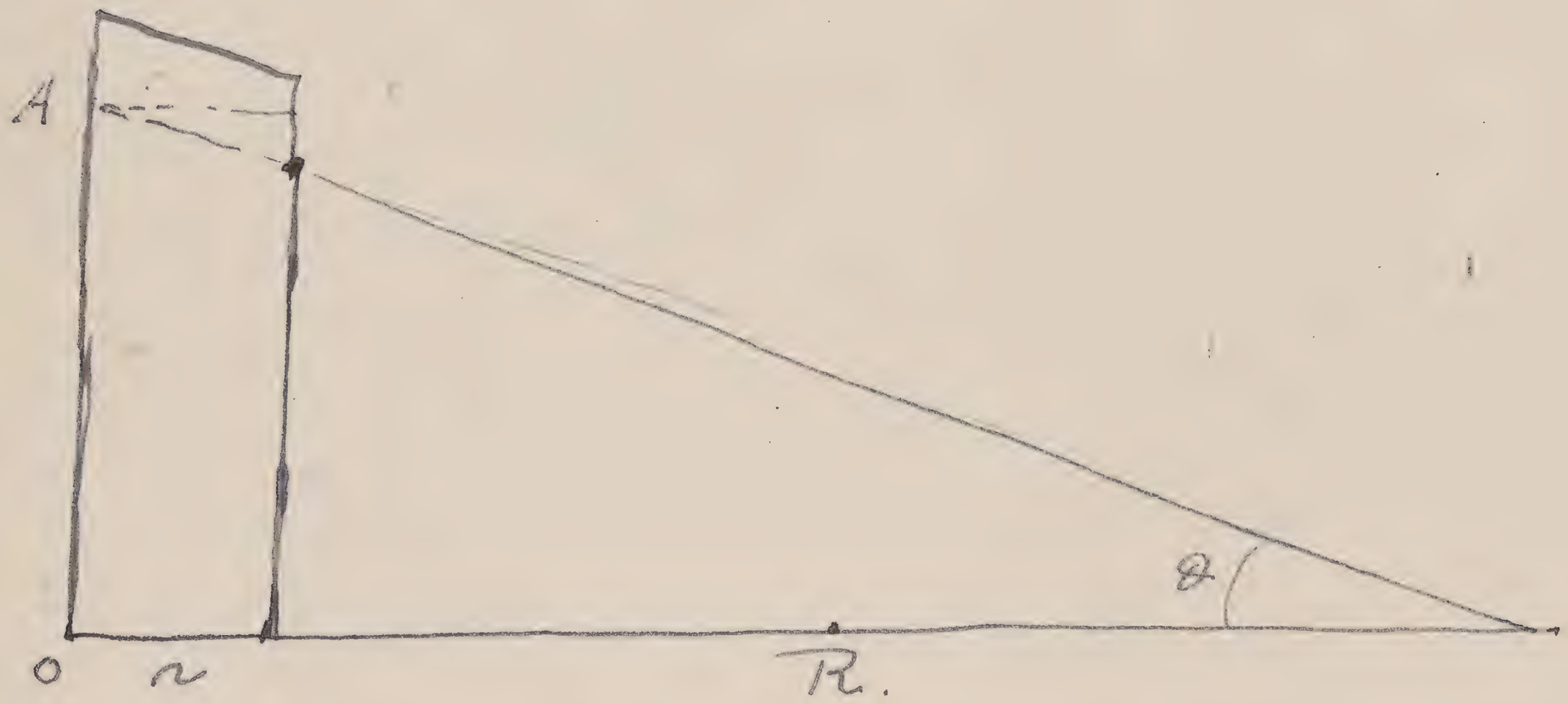
to make this a maximum, diff. with respect to $p$.

$$\frac{dx}{dp} = r - \frac{nR}{p^2} = 0$$

$$r = \frac{nR}{p^2}$$

$$R = \frac{pr}{q}.$$

to get the largest current then we must make the internal and external resistances equal.




resistances measured along

axis of $\overline{x}$.

$r$ = resistance of cell.

$R$ = " " circuit.

$i$ indicate upwards the

difference of potentials at the

poles of the battery when the external

circuit is in;

$$\frac{V_1 - V_2}{R} = \tan\theta = \lambda.$$

The line representing the fall

in potential is a straight line.

Conductivity from one sphere to another.

Flow takes place from the one to the other.

$$I = -\frac{dV}{dr} S C.$$

$$S = 2\pi r l.$$

$$\therefore I = -2\pi r l \frac{dV}{dr} C$$

Integrating.

$$(V_1 - V_2) 2\pi l C = I \log \frac{r_2}{r_1}$$

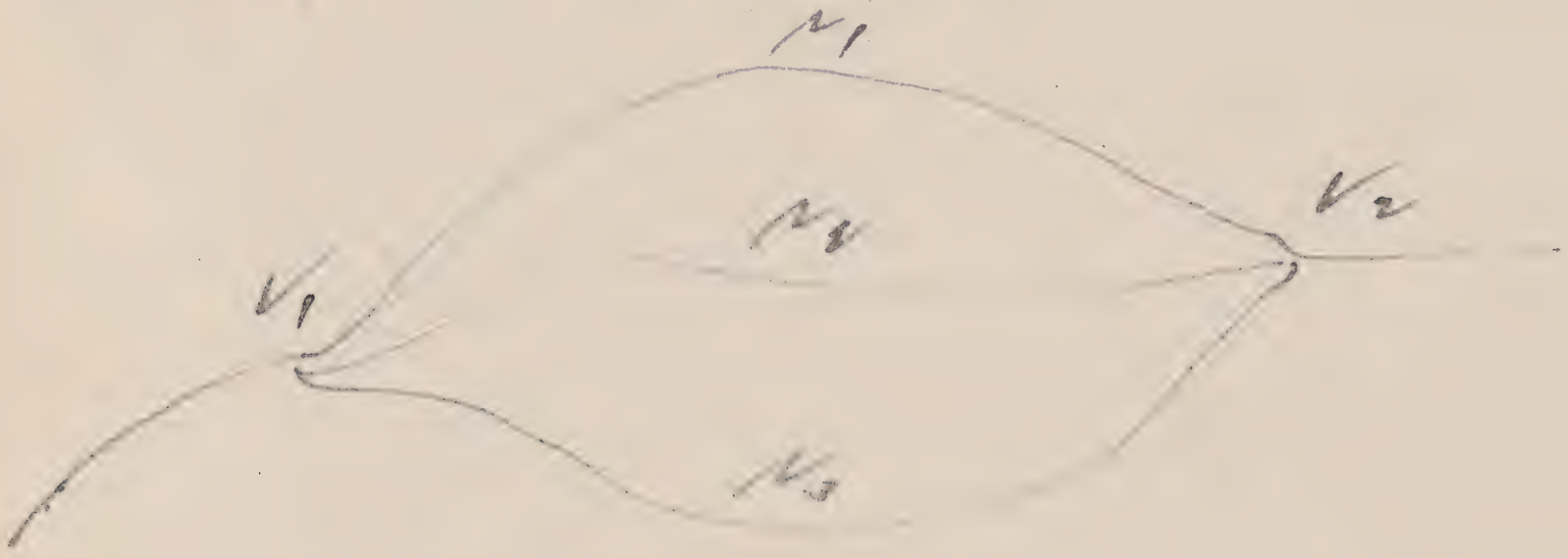
We also have from Ohms law

$$I = \frac{V_1 - V_2}{R}.$$

$$\therefore \frac{1}{K} = \frac{2\pi l C}{\log r_2/r_1}$$

and this expression for the conductivity is 4π times the capacity. Whenever we have from one system to the other we must substitute this factor in

Currents in a divided circuit




$$I_1 = \frac{V_1 - V_2}{r_1} = \frac{E}{r_1}$$

Putting E for the electro-motive force, $V_1 - V_2$

$$I_2 = \frac{E}{r_2}, \quad I_3 = \frac{E}{r_3}, \text{ etc.}$$

The total current will be

$$I = \frac{E}{r_1} + \frac{E}{r_2} + \frac{E}{r_3} = \frac{E}{R}$$

We must find R in terms of $r_1, r_2, r_3$ etc

We have

$$E = I_1 r_1 = I_2 r_2 = I_3 r_3$$

$$= \frac{I_1}{\frac{1}{r_1}} = \frac{I_2}{\frac{1}{r_2}} = \frac{I_3}{\frac{1}{r_3}}$$

$$= \frac{I_1 + I_2 + I_3}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}}$$

The current is $\frac{1}{R}$ the total current.

$$\therefore \frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}$$

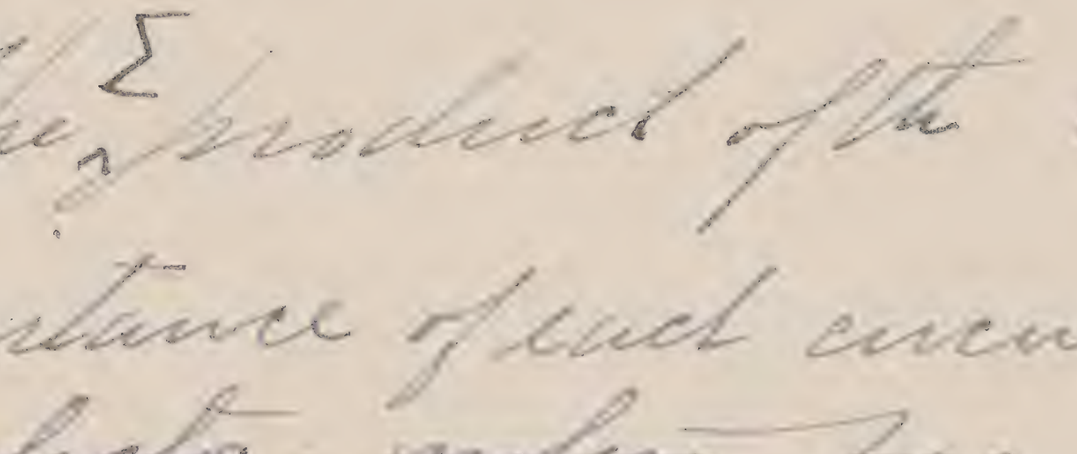
Kirchoff's laws for a network of conductors.

The sum of all the currents flowing into a point is equal to the sum of those flowing out. i.e.

$$I_1 + I_2 + I_3 = 0.$$

The $\Sigma$ product of the current and the resistance of each circuit is equal to the electro-motive force

$$\Sigma IR = E$$



We have.

$$\Sigma_3 r_3 = V_0 - V_2 + \mathcal{E}$$

$$\Sigma_1 r_1 = V_2 - V_3 \quad (-\mathcal{E}')$$

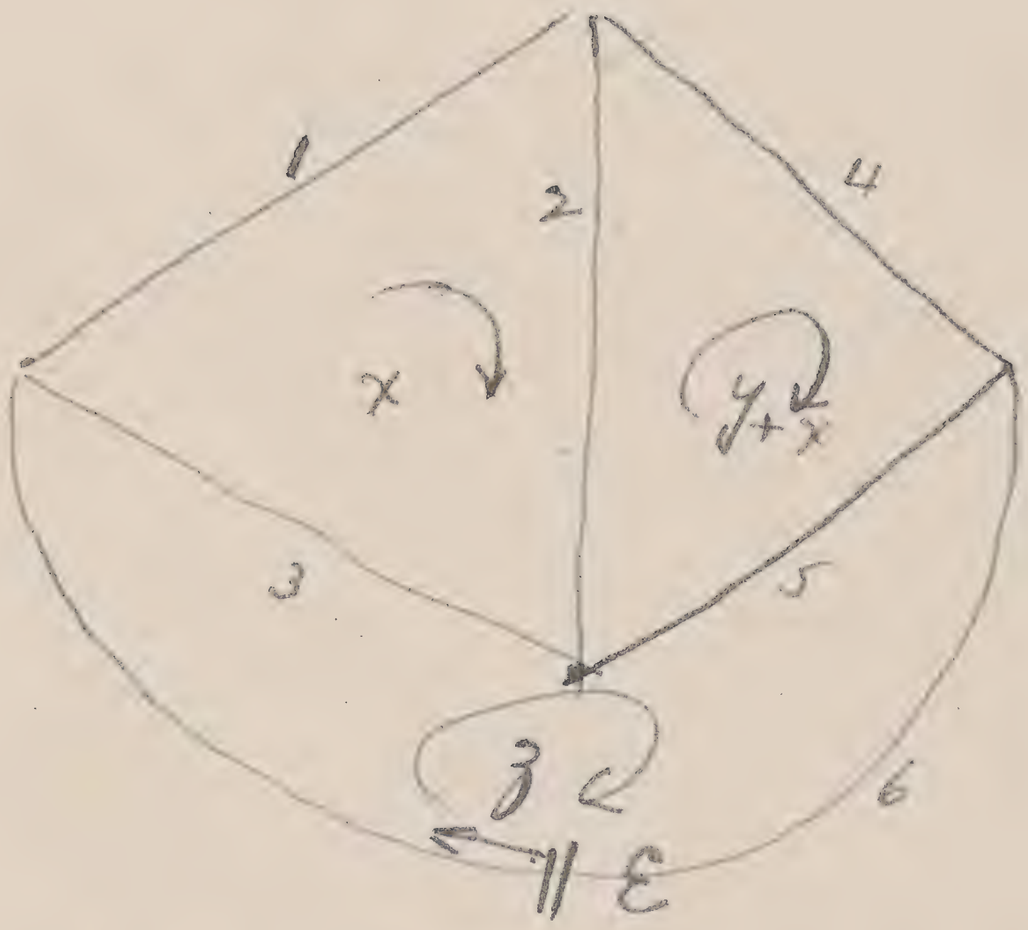
$$\Sigma_2 r_2 = V_3 - V_1 \quad (\cdot \mathcal{E}'')$$

$$\Sigma(\Sigma r) = \mathcal{E}$$

$\mathcal{E}$ is electro-motive force due to

Inductive -

Apply this to Wheatstone bridge.




We want to determine the current in wire which shall be zero.

We have the current in wire

x.

$$x i_1 - y i_2 + (x-z) i_3 = 0$$

$$+ y i_2 + (y+x) i_4 + (y+x-z) i_5 = 0$$

$$(z-x) i_3 + (z-x-y) i_5 + z i_6 = E$$

The three conditions that determine $i_1, i_2, i_3$.

The condition that there should be no current in the cross branch. i.e. $y = 0$.

ie

$$i_1 i_3 = i_2 i_4$$

Magnus – Boston Chemist –
Address communicated in Journ
in a Letter of Mr Mallet
Silver Ware is Chem-like
& Britannia metals –

The facts of thermo-electri-
city to which I am about to
call attention, are those
in which there is a discon-
tinuity in the thermo-electro-
motive force.

The above line is shown in
a simplified manner

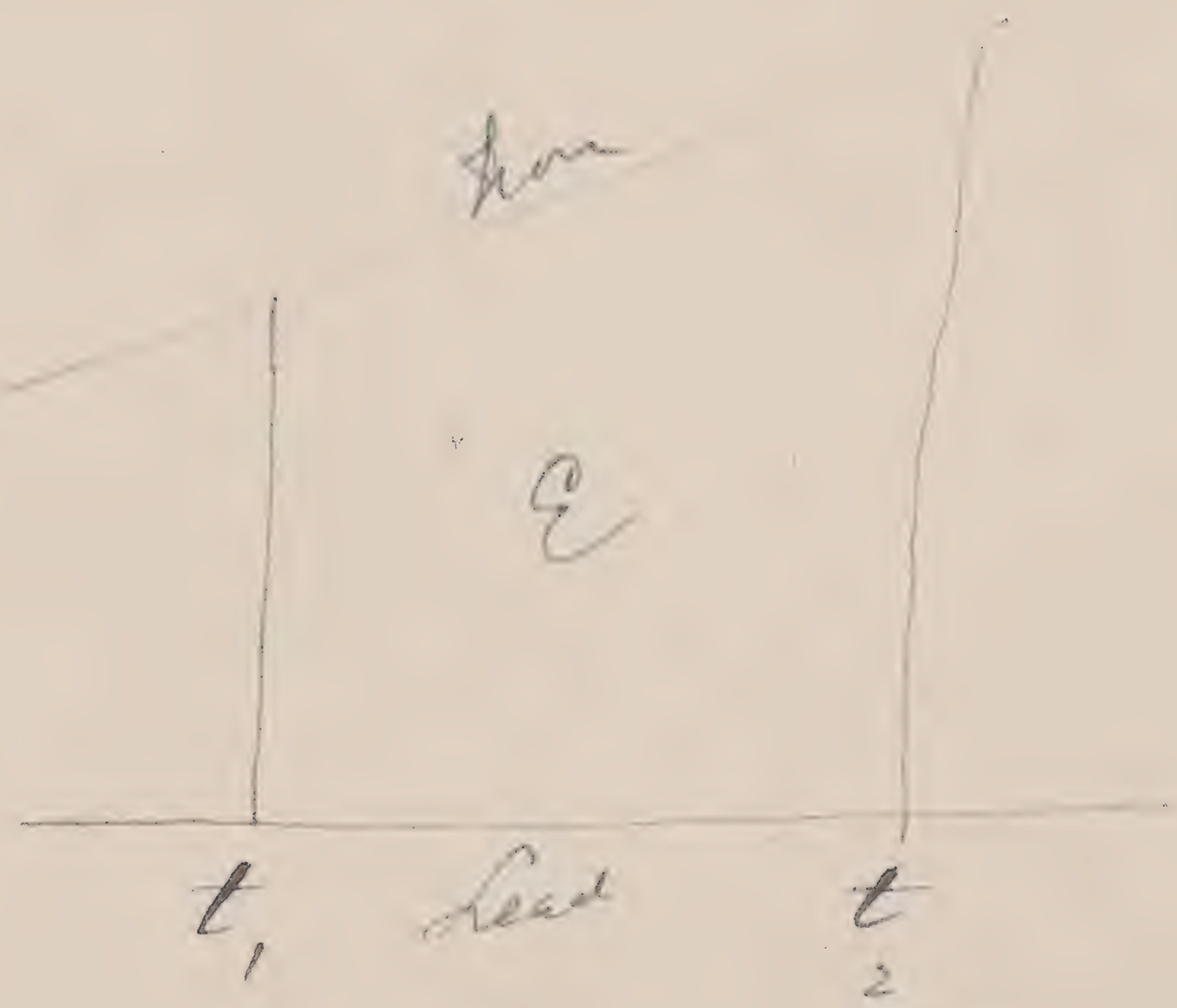
What is called thermo-motive force
in this circuit. — It is same as
if we had one piece of metal
B. one end at 0° and other at 3°

it against the mmf of the electro-motive forces of each pair is equal & the latter free.

Having thus discussed we come at once after the principle of conservation of energy.

Thermo-electric currents is meant that a certain, definite

Read




The work done when unit quantity of elec. flows across the

can neglect, we have.

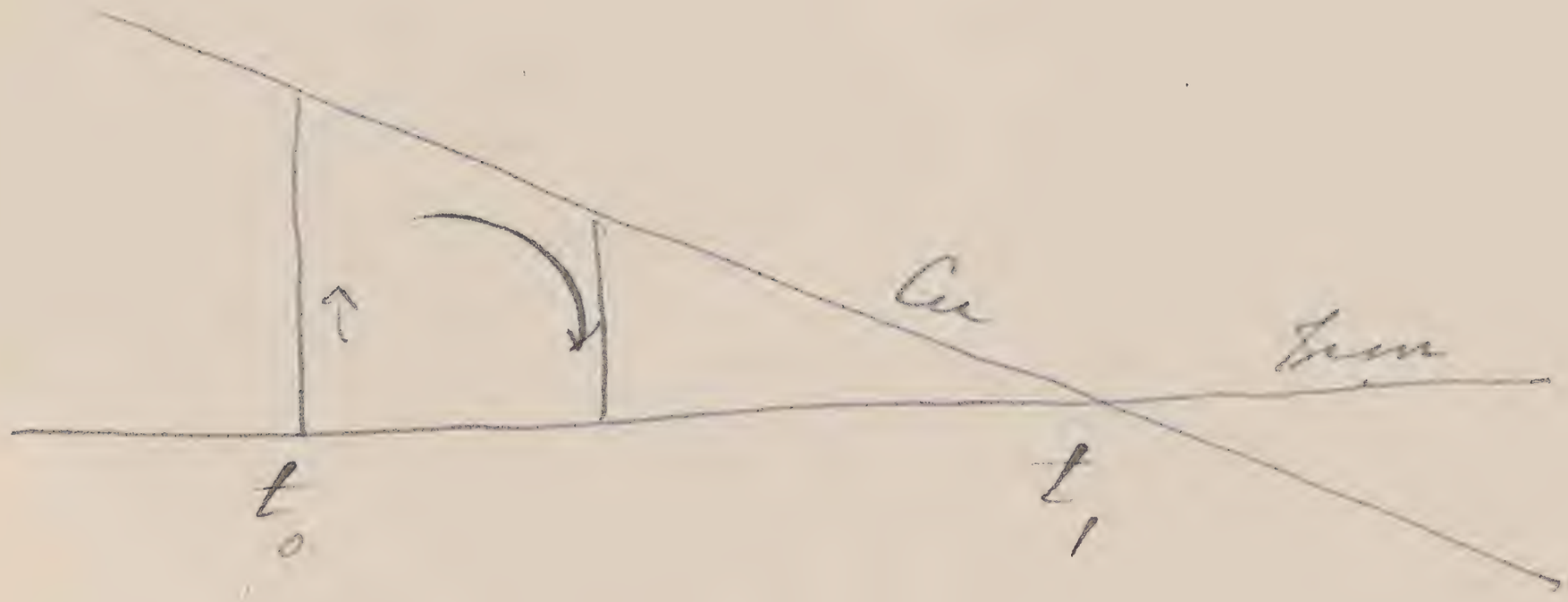
$$E\varphi = \text{work.}$$

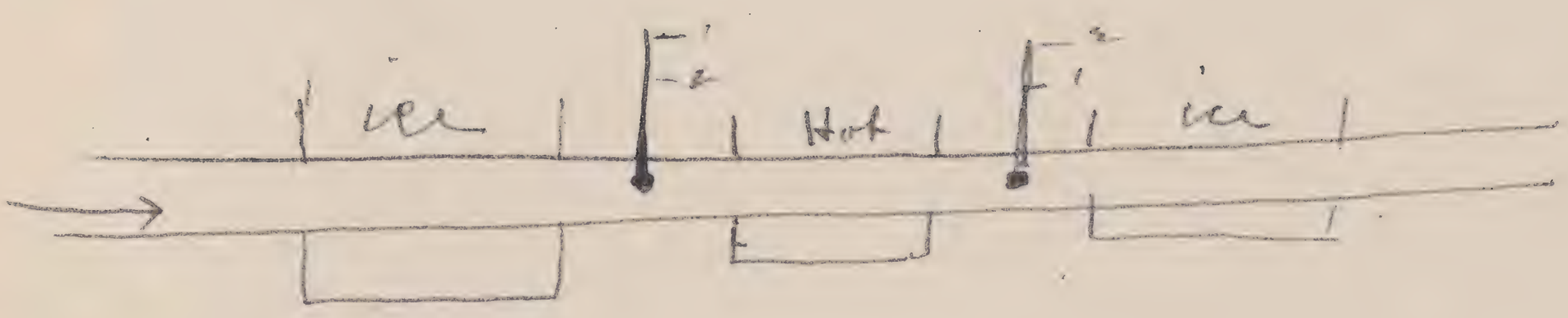
When work is done the
the area represents the work.

The work comes from the
heat, and this must be
a diminution of heat
mechanically equivalent to
that done.

Volta decomposed the
heat absorbed at the junctions.

Sir Wm. Thomson showed
that these processes are not
the only places where heat
is absorbed.



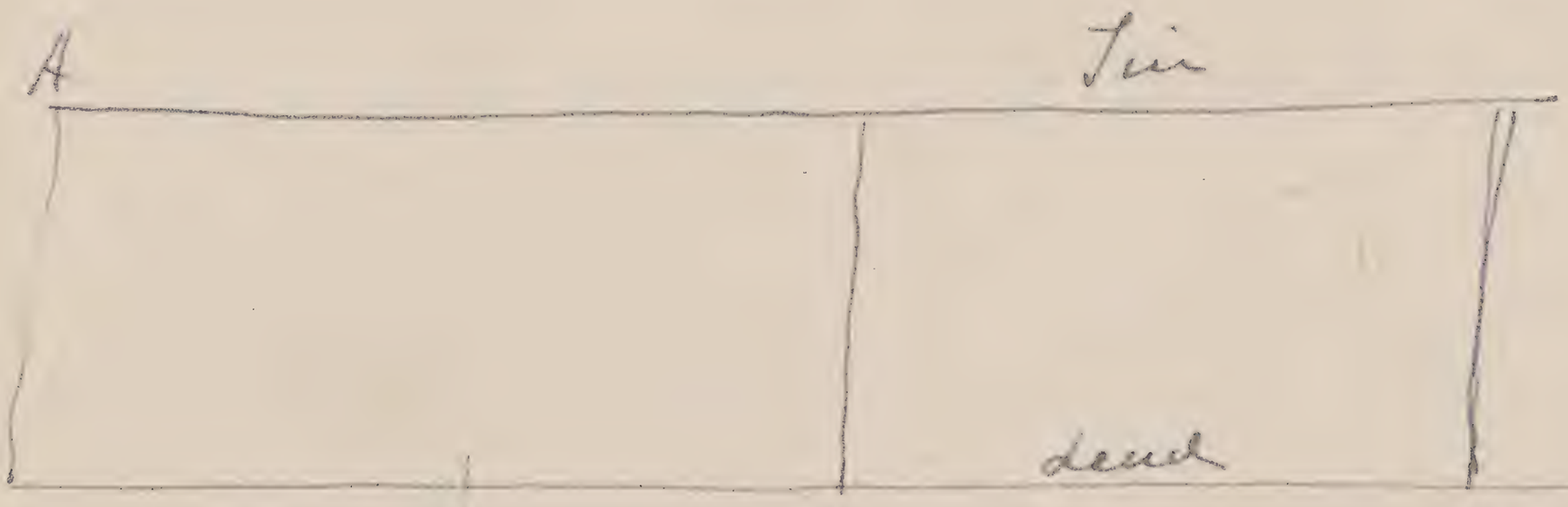




When the current was reversed there was a change in each thermometer. The thermometer in the glass which the current passes from cold to hot.

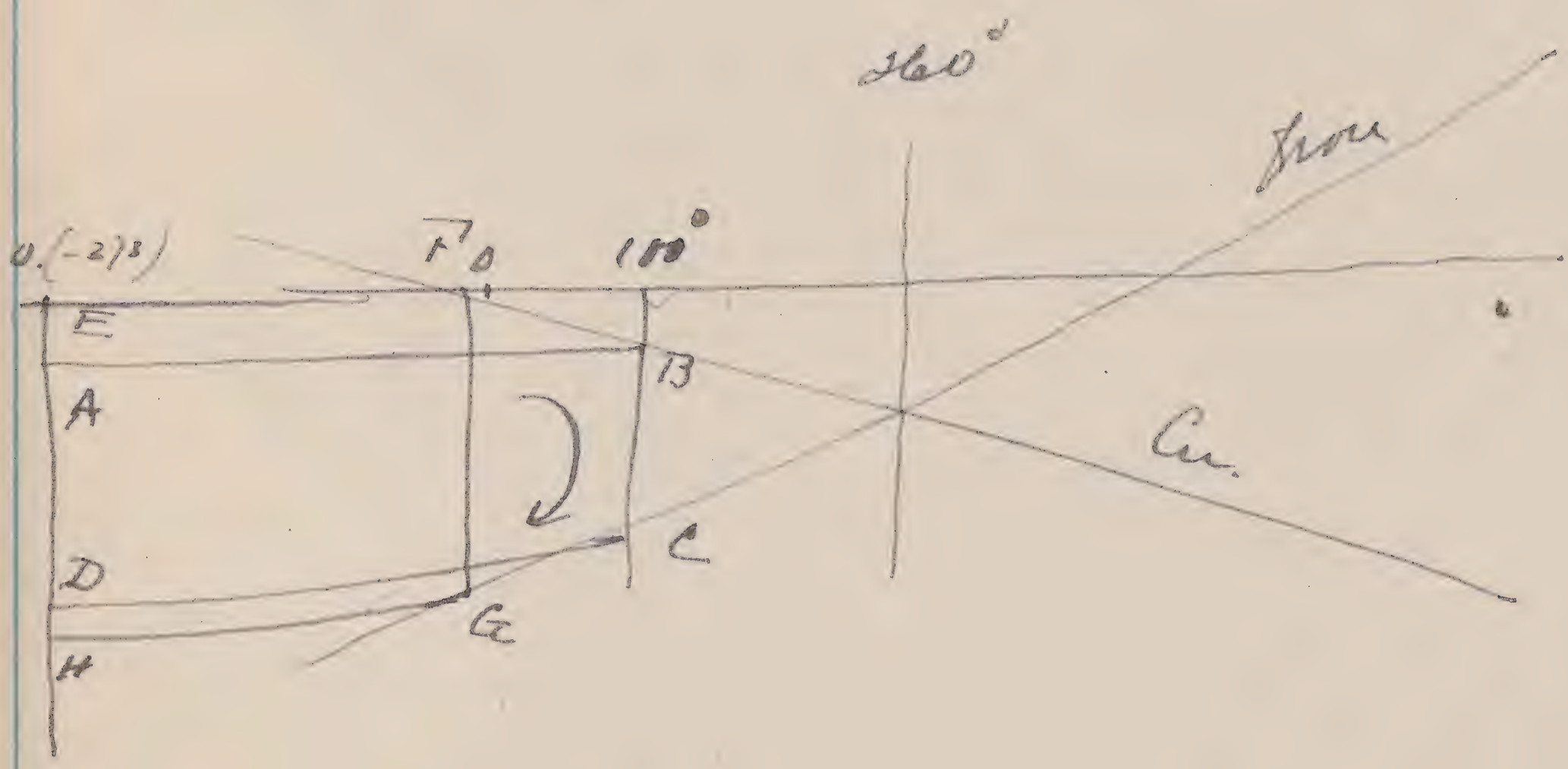
Lead is taken as base line for we find no thermo effect.

Whenever the current passes
from body of greater to lesser
thermo-elec. power,
heat is absorbed.

In any reversible heat engine
the heat taken in, heat given out
as absolute temperature, & heat given
out to that at which heat is
absorbed.




Line A corresponds to absolute
zero of thermo-dynamic scale.




EFBA represents heat absorbed in passage from F to B.

ABCD heat absorbed - due to known effect in iron.

And that given out is EFGH.

And

FBCG = AB - Iron and

To determine E.M.F. at any point.

$$\int \vec{E} = H = H' + h$$

H includes resistance. Even
though it not two parts, one due
to resistance and other to E.M.F.
If we change direction of current
h changes sign:

$$\int \vec{E} = H' + h.$$
$$\int \vec{E} = H' - h$$

The difference is $2h$. and we
have then

$$e = \frac{h}{\delta}.$$

to electro-motive force at the
function.

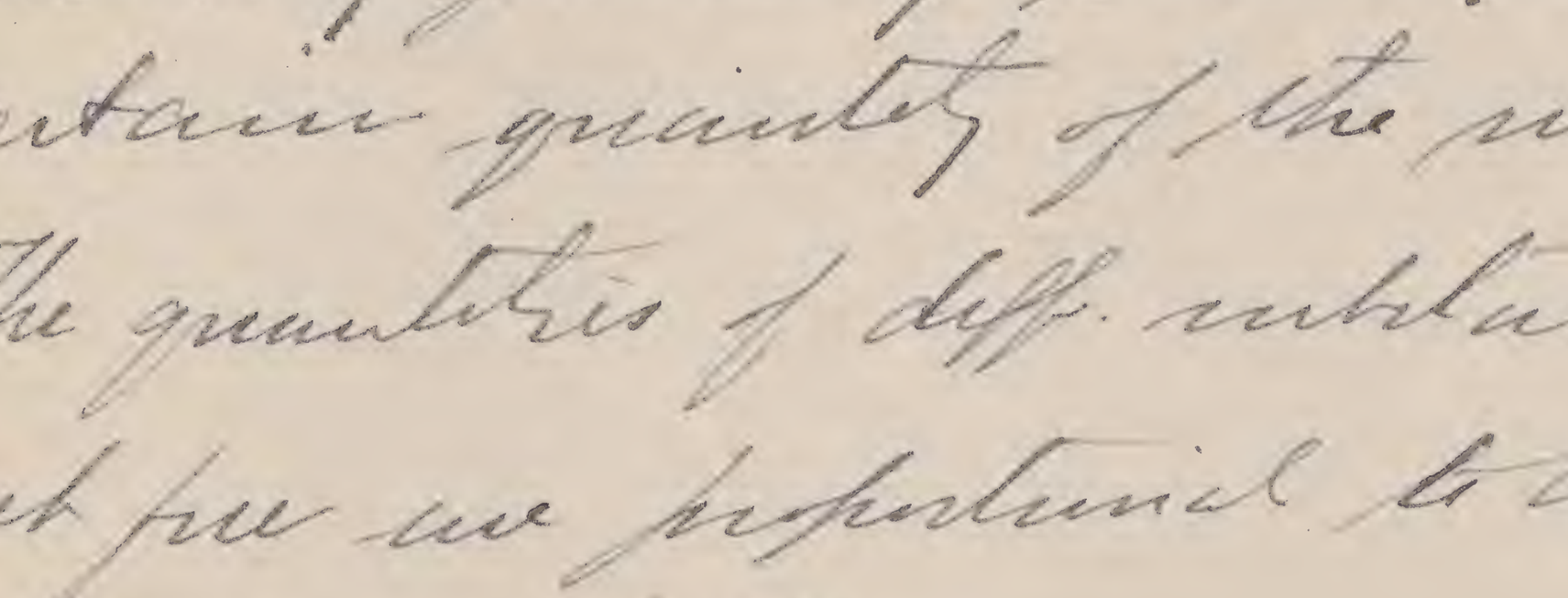
the action of current on an
electrolyte.

The results of the electrolysis may
be deferred upon the poles, either
as kyes of gas or as a true deposit.

Again the results may be
deferred

There may arise a secondary
effect, a chemical action; the
products may attack the poles
or the electrolyte itself.

In a given quantity of
electricity passing electrolyses a
certain quantity of the substances
The quantities of diff. substances
set free are proportional to their
atomic weights.



$\frac{v}{3}$ .

$v$

$\frac{v}{3}$